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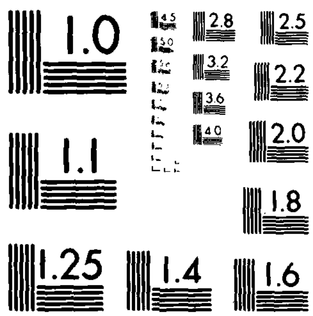

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Forward Area Alerting Radar Data Link

Results of European Tests

LEVEL

DEPARTMENT OF THE ARMY
HEADQUARTERS UNITED STATES ARMY COMMUNICATIONS
RESEARCH AND DEVELOPMENT COMMAND
FORT MONMOUTH, NEW JERSEY 07703

DRDCO-SEI-V 13 JAN 1981

SUBJECT: European Data Link Evaluation

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1. Transmitted herewith is the report of the European Data Link Evaluation conducted by the Center for Systems Engineering and Integration for PM, Air Defense Command and Control Systems. This final report entitled, "Forward Area Alerting Radar Data Link, Results of European Tests" was produced by the MITRE Corporation in response to tasking by CENSEI.

2. This report is an accurate reflection of data gathered during a two-week period in West Germany during May 1980. One should not make direct correlations relative to the acceptability of the various communications equipment assemblages with respect to the Air Defense Artillery mission. These assemblages were developed to gather empirical data regarding the capability of existing hardware to transmit and receive data in a pseudo-tactical situation.

3. Although significant differences in received bit error rate (BER) were not observed at speeds of 600 and 1200 bits per second (BPS), it must be noted that the Link Evaluation Test Set (LETS) modems were not optimized for these rates. A different modem, such as may be found in a Digital Communications Terminal (DCT) or Digital Message Device (DMD) may yield other performance results. Furthermore, it should be noted that in the encrypted mode of operation, the transmitted data rate was not optimized. The rate was that of the VINSON (16 KBS) in all cases, regardless of modulation rate.

4. The results of these tests indicate that adverse terrain conditions are more significant to acceptable communications than are data rates or distances between stations (up to the VHF maximum ranges). Therefore, it may be necessary that ADA planners and others attempting to use tactical data communications optimize radio station deployments based upon sites selected with respect to terrain constraints in order to achieve communications reliability acceptable for high speed data transmission. Antennas new to the

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tactical environment (OE-303, OE-254, OE-314) can, in many cases, provide more reliable communications in adverse terrain conditions. However, the use of such antennas alone will not always insure high quality communications.

John E. McNett

1 Incl
as

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Project Leader

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Forward Area Alerting Radar Data Link

Results of European Tests

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ABSTRACT

In the spring of 1980 a joint CORADCOM-MITRE evaluation team joined a Short Range Air Defense (SHORAD) unit in the field to investigate ways for improving the performance of the data link connecting SHORAD weapons teams with the Forward Area Alerting Radar (FAAR). The team conducted over 1000 data transmission tests over a period of seven days using several different antennas and data rates. These tests traversed a variety of ranges and terrain profiles closely representing operational European conditions. Using a MITRE custom-built data link test set and other supporting equipment, bit error rates, error distributions, and signal levels were recorded for each test. Test results demonstrated that the current FAAR data link rate could be tripled with little change in performance. Furthermore, communications to sites with weak reception and high error rates can be substantially improved using the alternative antennas evaluated during the tests. Based on these and other findings MITRE makes specific recommendations to the Army on improving FAAR data link performance.

ACKNOWLEDGMENT

We are very grateful to Rollin P. Mayer and Dr. Shiraz G. Bhanji, who were responsible for the test set microprocessor and software designs. Without their contributions, often on their own time, this project clearly could not have met its objectives and schedule.

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EXECUTIVE SUMMARY

Tests of the data link between the Forward Area Alerting Radar (FAAR) and simulated Short Range Air Defense (SHORAD) weapons outsites conducted in Europe demonstrated that: (1) better antennas significantly improved data link access at weapon sites; (2) intervening terrain was more significant than range in determining FAAR data link quality; (3) changes in data rate (between 600 and 2400 bits per second) and in interface (unencrypted audio frequency shift keying (FSK) or encrypted digital baseband) made little difference in data link performance; (4) giving the weapon teams a means of reading relative received signal strength enables them to improve data link reception; (5) few tests had errors - most performed flawlessly or not at all.

The FAAR transmits early warning on enemy aircraft over an FM data link to a portable display used by the SHORAD weapon team. The warning indicates approximate location and direction of travel of the intruder. However, this data link has shortcomings in range, reaction time and capacity which limit its effectiveness in the field. The Army is now investigating ways to improve performance of the data link used in the current FAAR. It is also designing an improved version of the FAAR, which will include new data link equipment.

To support both efforts, the Center for Systems Engineering and Integration (CENSEI) of the U.S. Army Communications Research and Development Command (CORADCOM) asked MITRE to help plan and conduct on-site tests of the FAAR data link in Europe and to analyze the test data. These tests had two objectives:

1. To determine how much the current data link could be improved under operational terrain conditions that exist in Europe by using alternative FM data link antennas, and

2. To assess the relative performance of the data link when using higher (than current) data rates and other terminal equipment interfaces.

Between January and the end of April 1980, MITRE drew up a test plan supporting these objectives, designed and constructed a portable Link Evaluation Test Set (LETS), and conducted preliminary tests. In May, a joint CORADCOM-MITRE team joined an Air Defense Artillery Battalion in Germany to conduct operational field tests. The team conducted over 1000 tests in seven days.

In these tests the team compared data link performance using 4 antennas: the currently fielded AS-1729/VRC whip, and the higher-gain OE-254 elevated omnidirectional, the OE-303 directional half-rhombic, and the OE-314 directional log periodic antennas. The data link was also tested at 600, 1200, and 2400 bits per second using unencrypted FSK and encrypted digital baseband interfaces. Bit error rates and distributions were compared to derive the relative quality of each configuration. Received signal level measurements and notes taken by test personnel also helped in performance evaluations.

Analysis of the test data resulted in the following observations:

a. Alternative antennas can significantly improve overall data link performance.

   1. Using higher gain antennas distinctly improved link performance in two ways at sites with weak reception. First, better antennas permitted communication to sites previously without any communications. Second, better antennas substantially reduced bit error rates observed at those sites that had high error rates when using whips.

   2. The OE-303 directional half-rhombic antenna seemed well-suited for use at weapon outsites due to its superior performance, low bulk, ruggedness, quick set-up and tear-down capability, and reputed resistance to off-angle jamming. In addition, use of the OE-254 elevated omnidirectional antenna at the FAAR improved data link performance by improving received signal strengths.

b. The nature of the terrain between the FAAR and the simulated weapon outsites was more important than range in determining link reception quality and error rates for ranges up to 20 kilometers.

c. Encrypted data can be transmitted at rates at least as high as 2400 bits per second (bps) over the FAAR data link using AN/VRC-12 series or similar radios. Under marginal field reception conditions there was no significant difference in bit error rate performance when the data rate was raised to 2400 bps. If unencrypted binary FSK is to be transmitted through the radio's audio circuits, radio design limitations do not permit any standard rates higher than 1200 bits per second to be used.

d. Data link tests at all data rates were in most cases either error-free or unreceivable. Only in one in seven instances (or 14%), on the average, did performance levels fall in between these extremes.

e. When operating with the weakest useable received signal levels at the data link receiver, a relatively small change in these levels produced a marked change in overall reception quality and error rates. The current data link receiver does not display received signal levels for optimizing reception.

f. Inclusion of encryption, and consequent changes from low-level digital to FSK formats, caused no significant change in link performance. Moreover, no change in link performance was noted with the presence or absence of radar radiation.

g. Both stationary and time-varying error rates were observed during the field tests. Under good reception conditions error rates were better than 10^{-5}. Under poor reception conditions error rates were higher and tended to vary in time during the test.

Based on these observations, MITRE recommends:

a. The Army should improve the present FAAR data link by:

   1. Issuing OE-303 half-rhombic directional antennas to SHORAD weapons teams for use at weapons outsites, and

   2. Issuing the OE-254 elevated omnidirectional antennas to FAAR teams for use at FAAR locations.

b. If the FAAR and its data link are to be improved, the Army, in addition:

   1. Can use an encrypted 2400 bits per second link for FAAR to weapon data communications, if required,

   2. Should give the weapon outsite receiver operator a means to read data link received signal levels for optimizing site selection and antenna installation, and

3. Should compare the benefits and costs of incorporating an error detection and correction scheme versus improving the received signal levels for reducing errors. Increased signal levels strongly improved bit error rates without the electronic complexity and extra message bits required for error detection and correction.

1.0 INTRODUCTION

1.1 Background

The Army uses Short Range Air Defense (SHORAD) weapons, currently comprising the Chaparral missile, the Vulcan gun, and the Redeye or Stinger shoulder-fired missile for short range defense against low altitude enemy aircraft. The weapon operators acquire their targets visually. But since terrain, vegetation, and other ground level obstacles can easily obscure low flying targets seeking to avoid visual detection, the U.S. Army fielded the Forward Area Alerting Radar (FAAR) to give early warning to SHORAD weapon teams on the imminent approach of enemy aircraft to their sectors. The FAAR transmits this warning over an FM data link to a portable display used by the weapon team.

However, several deficiencies in the current data link limit the FAAR's effectiveness for providing warning to the SHORAD weapon operator. First, when operating in European terrain, weapon teams frequently cannot receive the FAAR's transmission at weapon sites beyond ranges of eight to ten kilometers from the FAAR, falling well short of the radar and data link's design specification of 20 kilometers. As a result many weapon teams within a FAAR's area of coverage get no early target warning from the FAAR. Second, since the FAAR operator must manually enter all target information into the data link from the FAAR display, the warning response is slow and limited to a small number of targets (five or six) before the FAAR operator is overtaxed. Third, the current warning display at the weapon, known as the Target Alert Data Display System, or TADDS, does not provide adequate information or resolution on the targets presented.

The Army is dealing with these deficiencies in two ways. The Communications Systems Engineering Program (CSEP) Office, charged with finding and implementing ways to improve quickly the performance of current tactical communications, is investigating ways to improve the range and reliability of the data link by substituting better antennas at the FAAR transmitting site and at the weapon receive site. In addition, the Air Defense Command and Control Systems (ADCCS) Project Office is considering design improvements to the data link as part of a program to field an improved FAAR. These improvements include design of a rapid, automatic interface between the radar and the data link and increasing the capacity and information content of the link itself.

In January 1980 the Center for Systems Engineering and Integration (CENSEI) of the U.S. Army's Communications Research and Development Command (CORADCOM) asked MITRE to help plan* and conduct on-site tests of the FAAR data link in Europe and to analyze the test data collected. These tests were structured to contribute to both CSEP and ADCCS plans to identify and implement data link improvements.

1.2 Objectives

The FAAR data link tests had two objectives:

1. To determine how much the current data link could be improved under operational terrain conditions that exist in Europe by using alternative antennas, and

2. To assess the relative performance of the data link when using higher (than current) data rates and other terminal equipment and interfaces.

*Appendix I contains several planning papers which MITRE developed and used in this task.

The following sections describe the conduct of the tests, the results and conclusions, and MITRE's recommendations. The report also includes a brief description of the custom-built Link Evaluation Test Set (LETS) used in these tests for data collection in the field.

2.0 APPROACH

2.1 General

To meet the test objectives, a joint MITRE-Army team* investigated two aspects of the FAAR data link.

First, four different antennas were tested to determine the relative data link improvement each could contribute. The antennas tested were models either entering or already in the Army inventory or available as fully militarized prototypes under consideration for Army acquisition. Both directional and omnidirectional antennas were used in the tests.

Second, test data at three data rates in both encrypted and clear modes were transmitted from the FAAR to the test outsites. The data received at the outsites was compared to the transmitted data. Errors in the received data were the figure of merit used to evaluate different test configurations.

Test conditions were designed to duplicate actual operational conditions as closely as possible so that the test results could be related to expected field performance. Army personnel chose sites suitable for actual battlefield operations for both the FAAR and the data link receiver outsites (the latter simulating suitable weapon locations).

---

*The Army team included participants from the Communications Research and Development Command (CORADCOM), the Center for Systems Engineering and Integration (CENSEI), United States Army Europe (USAREUR) Headquarters, U.S. Army Air Defense School (USAADS), 32nd Army Air Defense Command (32 AADCOM), and the U.S. Army Signal Center and School (USASC&S). Representatives from the National Security Agency (NSA) were also present.

2.2 Test Design

2.2.1 Equipment

The test configurations stressed use of tactically configured military equipment. Figure 2-1 describes a block diagram of the test equipment and configuration used.

2.2.1.1 Radios. The FAAR's existing RT-524 transceiver used in the current data link was used for transmitting test signals from the FAAR.

The receiver portion of the TADDS currently used at the outsites was not practical for use in the tests, since it could not be made to interface readily with test equipment. In its place the FAAR data link receiver outsites used the R-442 auxiliary receiver which is part of the jeep-mounted AN/VRC-47 radio. This substitution did not materially affect the results since the R-442 is electrically equivalent to the receiver portion of the RT-524 and is reportedly similar to the receiver used in the TADDS.

MITRE temporarily modified each R-442 receiver to extract a sensing voltage that was proportional to the received signal strength at low signal levels (less than ten microvolts). The sensing voltage was monitored with a portable voltmeter at each receiver. These measurements helped correlate received signal strength with reception quality.

2.2.1.2 Encryption Devices. Since the Army may add encryption to future versions of the data link, tests were conducted both with and without encryption devices. For this purpose the RT-524 transceiver at the FAAR and the R-442 portion of the AN/VRC-47 outsite

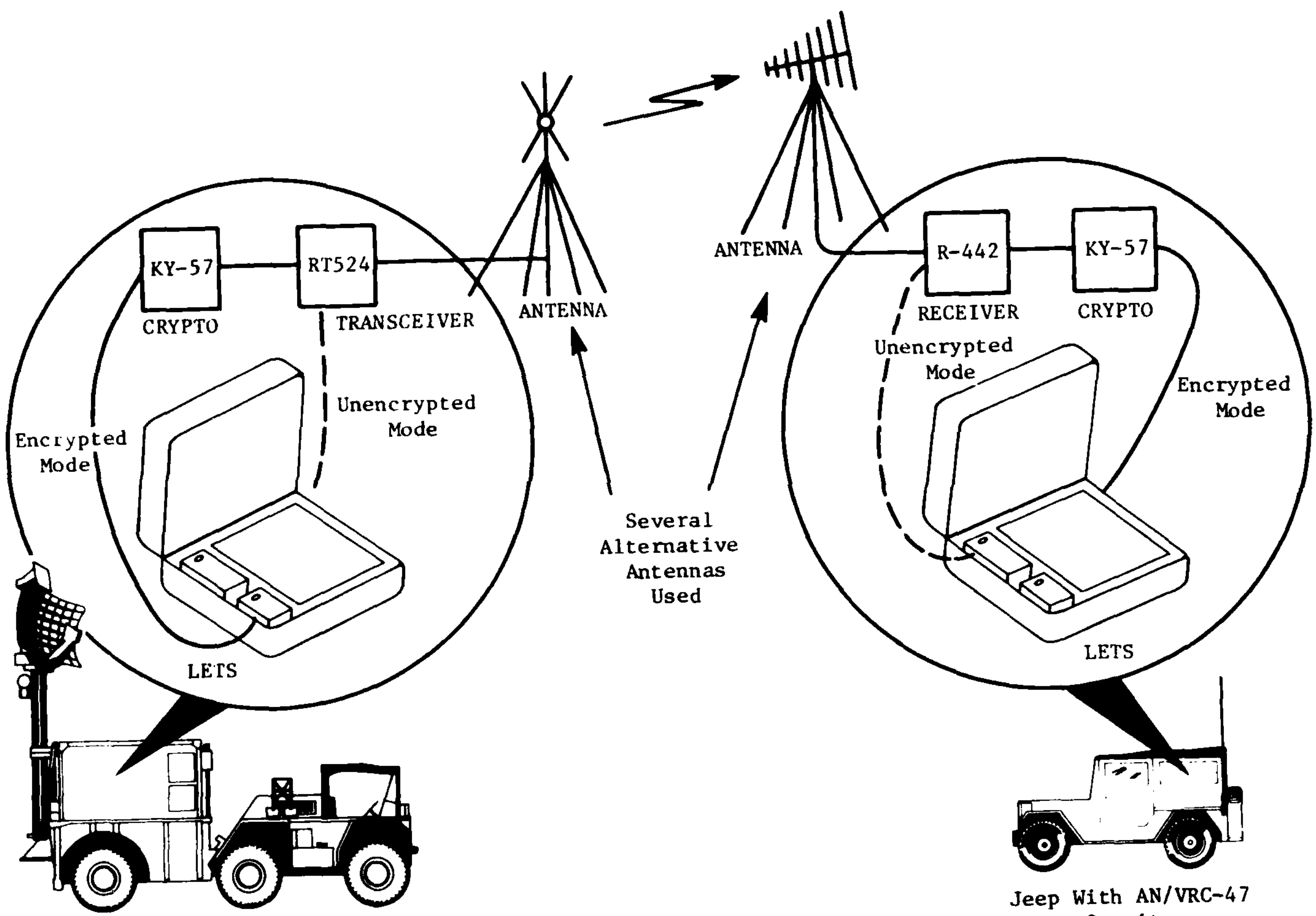


FIGURE 2-1
TEST CONFIGURATION DIAGRAM

terminals were temporarily modified to add a TSEC/KY-57 VINSON encryption device at each location. This new encryption device is now being fielded for use with the AN/VRC-12 series radios.

2.2.1.3 Antennas. The system was evaluated using four different antennas: the AS-1729/VRC tuned whip omnidirectional antenna, the OE-254 elevated omnidirectional antenna, the OE-303 half-rhombic directional antenna, and the OE-314 log periodic yagi directional antenna (see Figures 2-2 through 2-5). The AS-1729/VRC tuned whip antenna mounted on the FAAR shelter is the current standard FAAR data link transmit antenna.

Only the omnidirectional antennas (the AS-1729 and the OE-254) were used at the FAAR, since it must broadcast in multiple directions. However, since the outsites need only receive from one direction, both omnidirectional and directional antennas were evaluated at outsite locations.

2.2.1.4 Link Evaluation Test Set. No known military or commercial device was available providing the data rates, interfaces, and testing capability required for these data link tests. Therefore MITRE designed and built six portable microprocessor-based data Link Evaluation Test Sets (LETS) for this application. One was used at the FAAR location as a data source. Four others were used at the outsites for analysis of the received data. One was kept as a spare.

The LETS:

a. Generates and sends, or receives and checks, a pseudorandom series of 1000 8-bit random numbers simulating characters. Each such "character" is follows by an incrementing 8-bit binary digit. Each character and digit is preceded and followed by start and stop bits respectively. A complete test sequence comprises five such consecutive series. The test sequence therefore includes, in all, 10,000 characters and digits or 100,000 bits.

FIGURE 2-2
JEEPS AT ONE OF THE OUTSITES TESTED.
THE AS-1729 WHIP CAN BE SEEN ATTACHED TO THE REAR OF THE JEEPS.

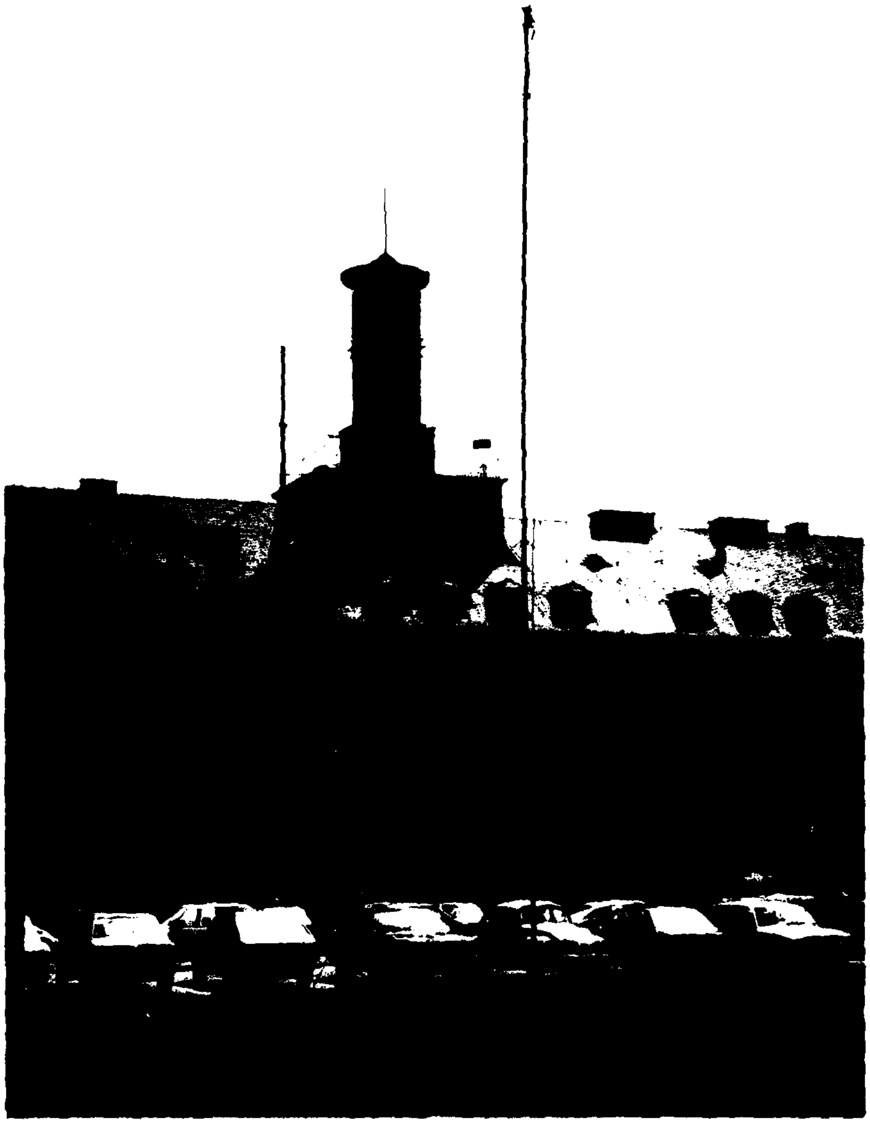


FIGURE 2-3
THE OE-254 ANTENNA

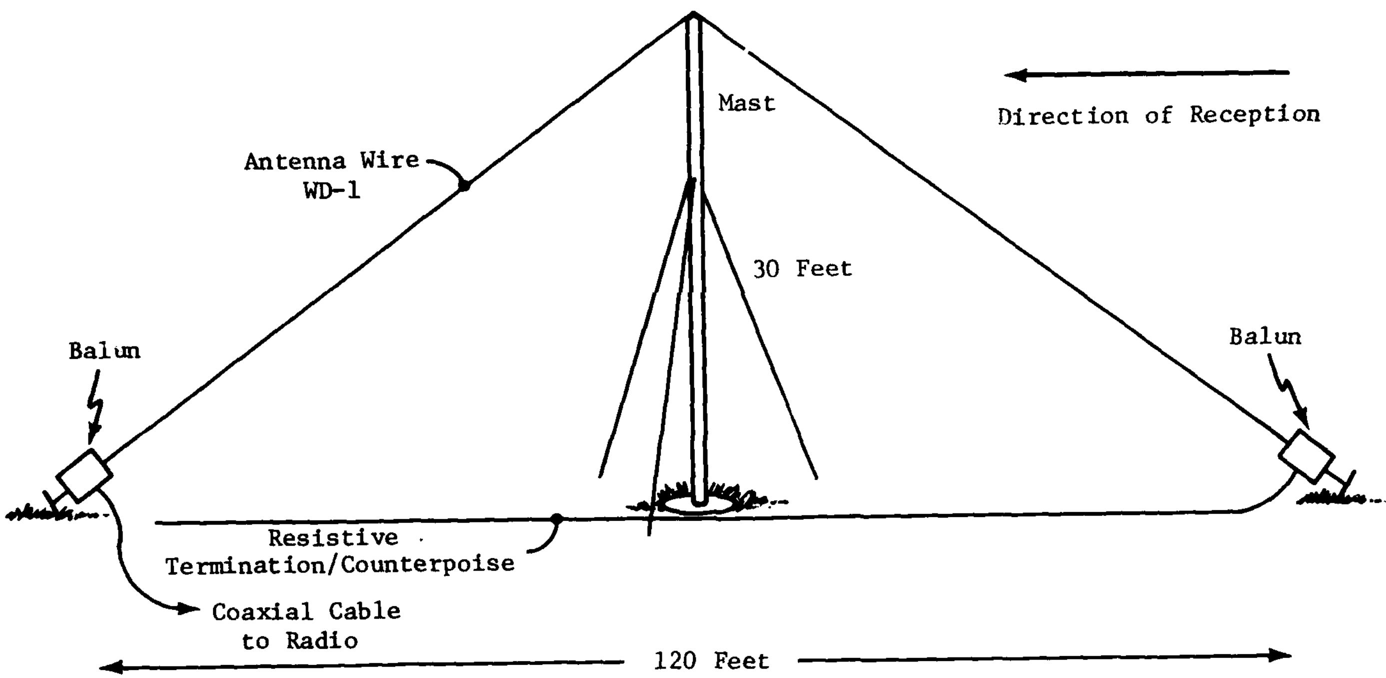


FIGURE 2-4
OE-303 HALF-RHOMBIC ANTENNA

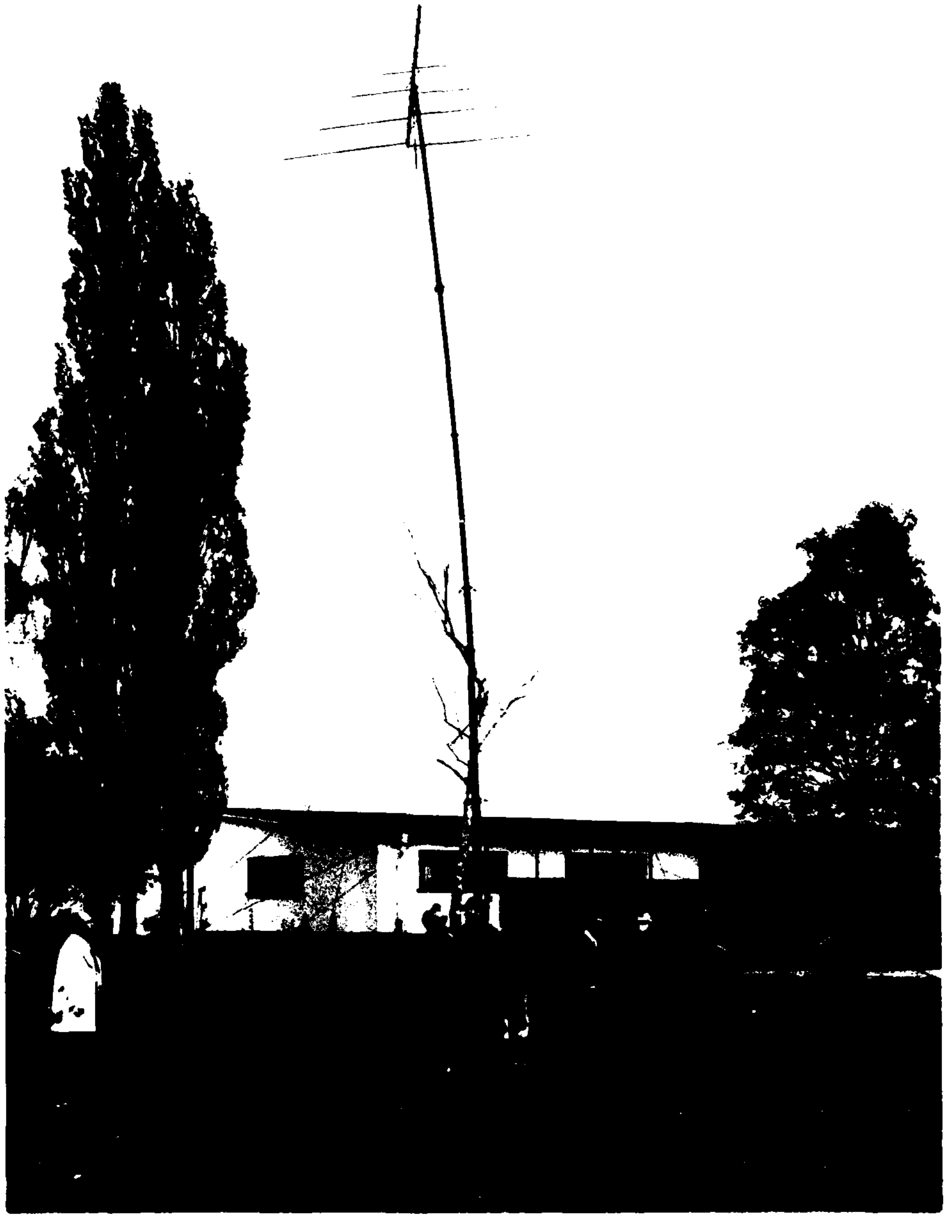


FIGURE 2-5
THE OE-314 ANTENNA.
DURING THE TESTS THE ANTENNA ELEMENTS WERE ORIENTED VERTICALLY (VERTICAL POLARIZATION) RATHER THAN HORIZONTALLY AS SHOWN.

b. Sends and receives data at the rates to be tested: 600, 1200, and 2400 Bits Per Second (bps),

c. Sends and receives at all data rates using low-level digital signaling ($\pm$ 6 volts), or at 600 and 1200 bps using audio frequency binary Frequency Shift Keying (FSK) signaling using shift frequencies of 1300 and 2100 Hertz. Both signaling approaches were taken from Military Standard 188,

d. Counts character and bit errors, and provides statistical distributions on bit errors when used as a receive terminal,

e. Interfaces with the RT-524, R-442, and TSEC/KY-57 (in both the digital and analog modes with the TSEC/KY-57), and

f. Operates from 24 volt vehicular power.

Figures 2-6 and 2-7 illustrate the LETS. Detailed design information on the LETS will be published under separate cover.

2.2.1.5 Other Equipment. For test coordination, test control personnel used an RT-524 at the operations center collocated with the FAAR to communicate over a separate engineering order-wire net to the outsite personnel. Outsite personnel used the RT-524 component of the jeep-mounted AN/VRC-47 and an antenna not otherwise in use for coordination.

2.2.2 Test Conduct

Each test began with coordination between the operations center and the outsite teams over the engineering order-wire on the tests to be run. This coordination included designation of the antenna to be used, the data bit rate, and mode (encrypted or unencrypted). Then the operations center notified the outsites on the start of each test, after which the LETS at the FAAR began transmission of a test sequence as defined above. During reception the outsite operator noted the signal level reading on the voltmeter attached to the R-442 receiver. After a full test sequence was received, the outsite

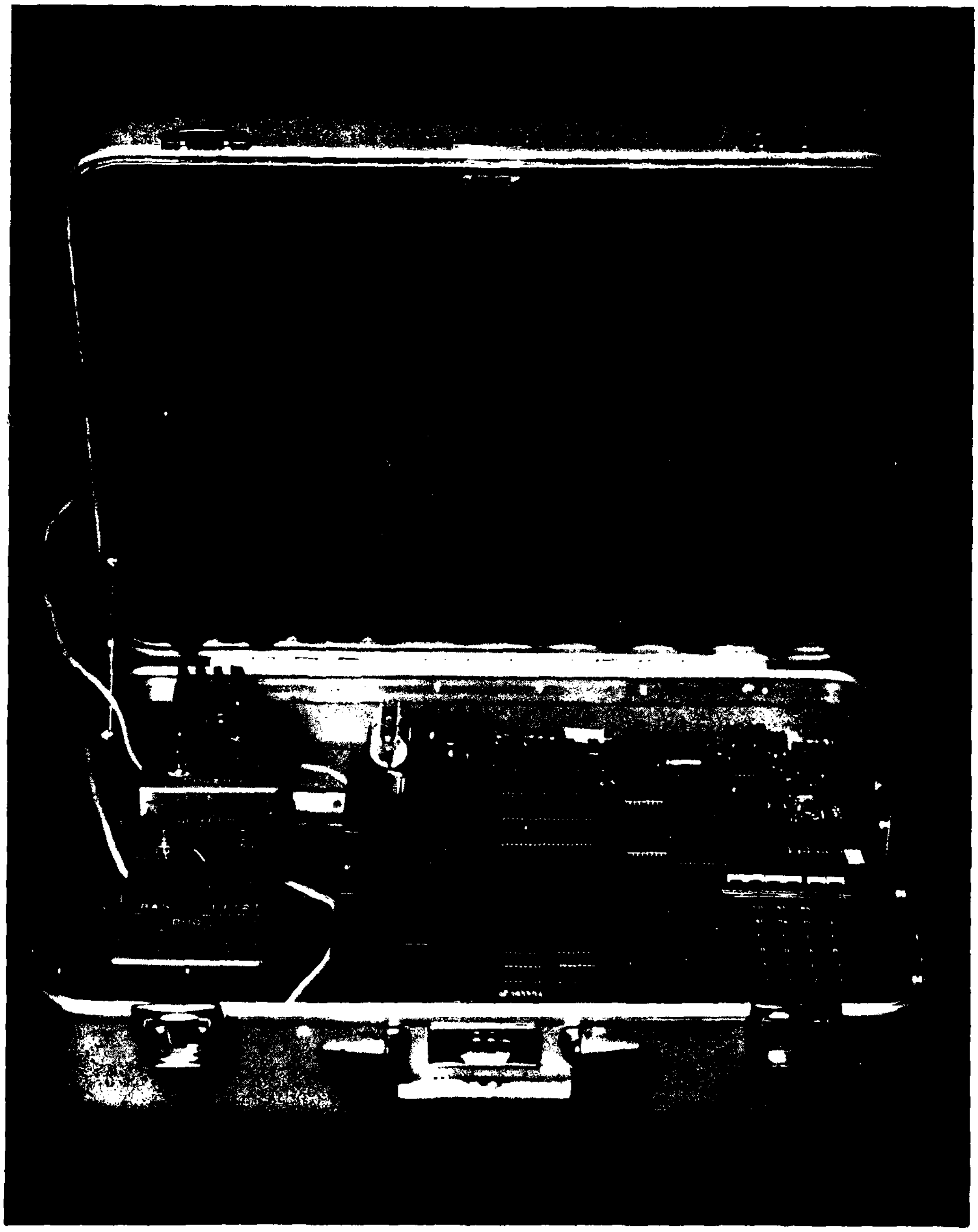
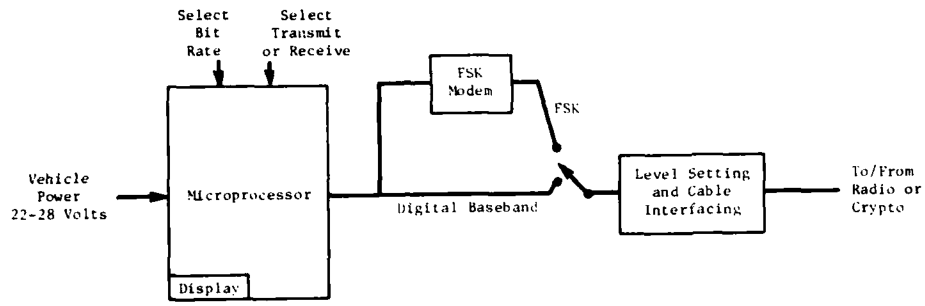
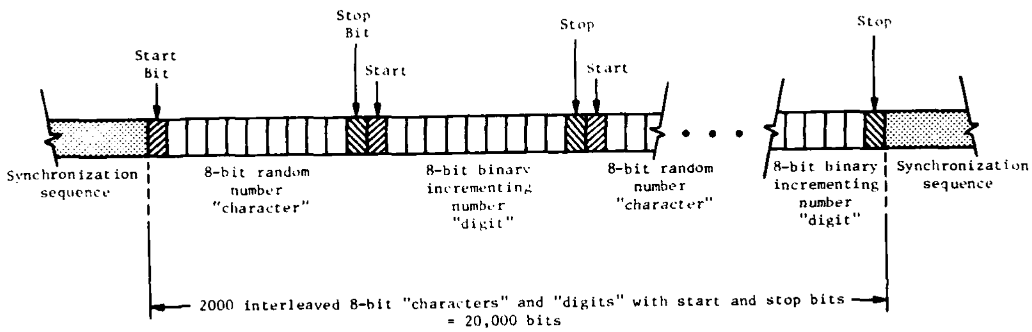


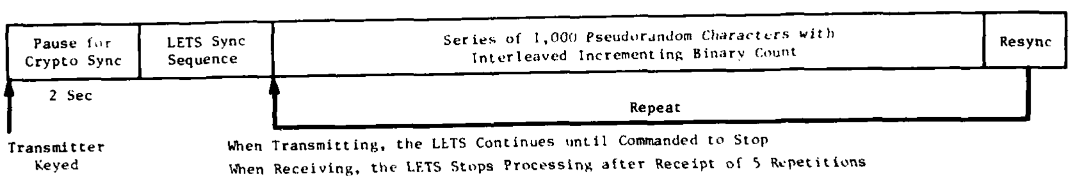
FIGURE 2-6
THE LINK EVALUATION TEST SET.
A PROTOTYPE VERSION IS ILLUSTRATED
WHICH CLOSELY RESEMBLES THE FINAL VERSION.



LETS BLOCK DIAGRAM



LETS TEST SERIES



TYPICAL TRANSMITTED TEST STREAM FORMAT

FIGURE 2-7
LETS BLOCK DIAGRAM AND TEST STREAM FORMAT

operator recorded the error statistics displayed by the LETS and reported an approximate total error count to the operations center. The test teams then proceeded to the next test.

Four outsite teams simultaneously collected data in this manner, each at a different location. These teams comprised military personnel on loan from Army units supporting the tests. On occasion a MITRE representative visited each outsite to gather supplemental information useful in interpreting test results. Table I lists the different antenna combinations tested.

TABLE I

ANTENNA COMBINATIONS TESTED

TEST	ANTENNA	
REFERENCE NUMBER	FAAR	OUTSITE
1	WHIP	WHIP
2	OE-254	WHIP
3	OE-254	OE-254
4	OE-254	OE-303
5	OE-254	OE-314
6	WHIP	OE-254
7	WHIP	OE-303
8	WHIP	OE-314
11	OE-303	OE-303
12	OE-303	OE-314

The Army test director chose all test sites in advance to conform to good weapons locations in a battle environment, based upon both map and ground reconnaissance. In general, sites were selected from five to forty kilometers from the FAAR. Terrain profiles between the FAAR and the outsites had features characteristic of the West German landscape. Profiles often included intervening towns, roadways, power lines, and forested areas. A good line-of-sight terrain profile was not always a criterion for site selection.

Two testing approaches were employed. During the first five days of testing, each team evaluated one site per day. Sites were chosen at approximately 5, 10, 15, 20, 30, and 40 kilometers* from the FAAR, each representative of a Chaparral or Vulcan (C/V) site. The first eight antenna combinations listed on Table I were evaluated at all sites except those beyond 20 kilometers. Beyond this range testing concentrated on high gain antennas including configurations 11 and 12. All of the above tests are referred to as the C/V tests.

In the remaining two days of tests a different testing approach was used. To quickly gain an impression of the quality of a large number of sites, each of the four teams simultaneously and rapidly tested approximately seven sites per day, each suitable for a Redeye or Stinger (R/S) team. This test approach reflected the increased mobility and more austere equipment such teams normally have in comparison to the Chaparral and Vulcan teams. In most cases only tests employing the vehicle-mounted whip antenna at the outsites were conducted (Tests 1 and 2 in Table I). On four occasions the OE-303 half-rhombic was also tested. The tests conducted during these two days are termed the R/S tests.

*Sites at 30 and at 40 kilometers were evaluated the same day by different teams

The received bit and character error totals and bit error distributions, recorded by the military outsite operators, constitute the primary test data obtained from these two approaches. The outsite operators also noted the received signal level for each test. Occasional qualitative observations by the operators and by technical personnel visiting the sites supplemented these results when they shed additional light (such as to explain unexpected results). The observations and conclusions in Sections 3.0 and 4.0 are drawn from these test data.

2.3 Test Constraints

There were constraints on the project's scope and the resources available for the tests themselves. The four months available between the project's inception and the beginning of on-site testing limited the sophistication that could be employed in the overall test design. For example, the short lead time limited the degree to which extra or advanced features could be incorporated into the LETS, such as duo-binary FSK operation or some optimized filter techniques.

However, these constraints generally had the advantage of slightly worsening the data link operation. Optimized approaches should improve performance over that seen in these tests. Moreover, these constraints did not affect achievement of the test objectives nor the validity of the results.

Since field testing was limited to a single opportunity in May 1980, the effects of seasonal variations could not be observed in the tests. No inclement weather occurred during the test period, hence its effects also could not be observed. But season and weather should have little effect on data link performance in view of the low VHF frequencies used and the relatively short ranges tested.

The limited time available for the tests themselves in Germany permitted the use of only one FAAR location for test broadcasts and limited the total number of tests that could be conducted at each outsite. The area selected for tests was therefore chosen to represent average terrain in West Germany, insofar as practical. Within this context, over a thousand tests were conducted - enough to give a good picture of expected data link performance.

The radio equipment used for the tests was taken from operational inventory and checked for conformance with existing USAREUR specifications prior to the tests. This prevented unknown radio faults from coloring the test results. The FAAR was taken from the operational inventory of the 3/61 Air Defense Artillery Battalion in Europe.

Finally, all testing was accomplished in a peacetime electromagnetic and physical environment. Resources were not available for simulating hostile electronic countermeasures (ECM).

3.0 TEST OBSERVATIONS AND RESULTS

3.1 Overall Link Performance Summary

Over the course of the seven days of testing, a total of 1153 tests was conducted. Each involved an attempt to receive a complete test sequence as defined above (see 2.2.1.4) for a different combination of location, transmit and receive antennas, data rate, mode (encrypted or unencrypted), and day. Of this number, 1065 tests yielded useful information on link performance. The results of the remaining 88 tests were not useable due to equipment or procedural problems in testing. The 1065 useful tests are broken down in Table II by test type and reception quality.

TABLE II

BREAKDOWNS OF USEFUL TESTS

	CHAPARRAL/VULCAN TESTS		REDEYE/STINGER TESTS		TOTAL	
	No.	%	No.	%	No.	%
Test Transmissions	593	56	472	44	1065	100
Receptions with no Errors	499	84	198	42	697	65
Receptions with Errors	93	16	56	12	149	14
Unsuccessful Receptions	1	0.2	218	46	219	21

For the 1065 useful tests conducted, link performance tended to be either very good (zero bit errors) or very bad (too weak to operate). Only one in seven tests (14%) had countable errors.

Both the C/V and the R/S test results are similar in that only a small percentage of all tests had some number of errors. In both cases either error-free communications or a complete failure to communicate accounted for the large majority of tests conducted.

This behavior is a result of the inherent characteristics of wideband FM detection employed by the AN/VRC-12 series radios.* Wideband FM systems typically tend to provide either a very high quality signal output or none at all. The transition between these extremes occurs with only a small change in antenna input signal levels. Hence moderate improvements in receiver input signal levels, however achieved, can result in significant improvement in the quality of the received signal at the threshold of the detector, as illustrated in Figure 3-1. In this figure the vertical distance between the signal level and noise level is the output signal to noise ratio at the given receiver input signal level.

Hence any technique that will increase signal levels should have a significant effect on data link reception quality (i.e., reduction of the received bit error rate) when the received signal level is in this transition region.

3.2 The Effect of Range and Terrain on Performance

Tests demonstrated that adequate** link performance was determined not so much by range as by the nature of the intervening terrain out to the FAAR's operational range of 20 kilometers. In fact, error-free communications were possible out to 40 kilometers (the maximum range tested) if the intervening terrain blockage was

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*See, for example, S. Stein and J. S. Jones, Modern Communications Principles, McGraw Hill, Inc., 1967, Chapter 6, Section 6-5.

**That is, performance better than a given standard, such as, for example, a 10^{-3} bit error rate.

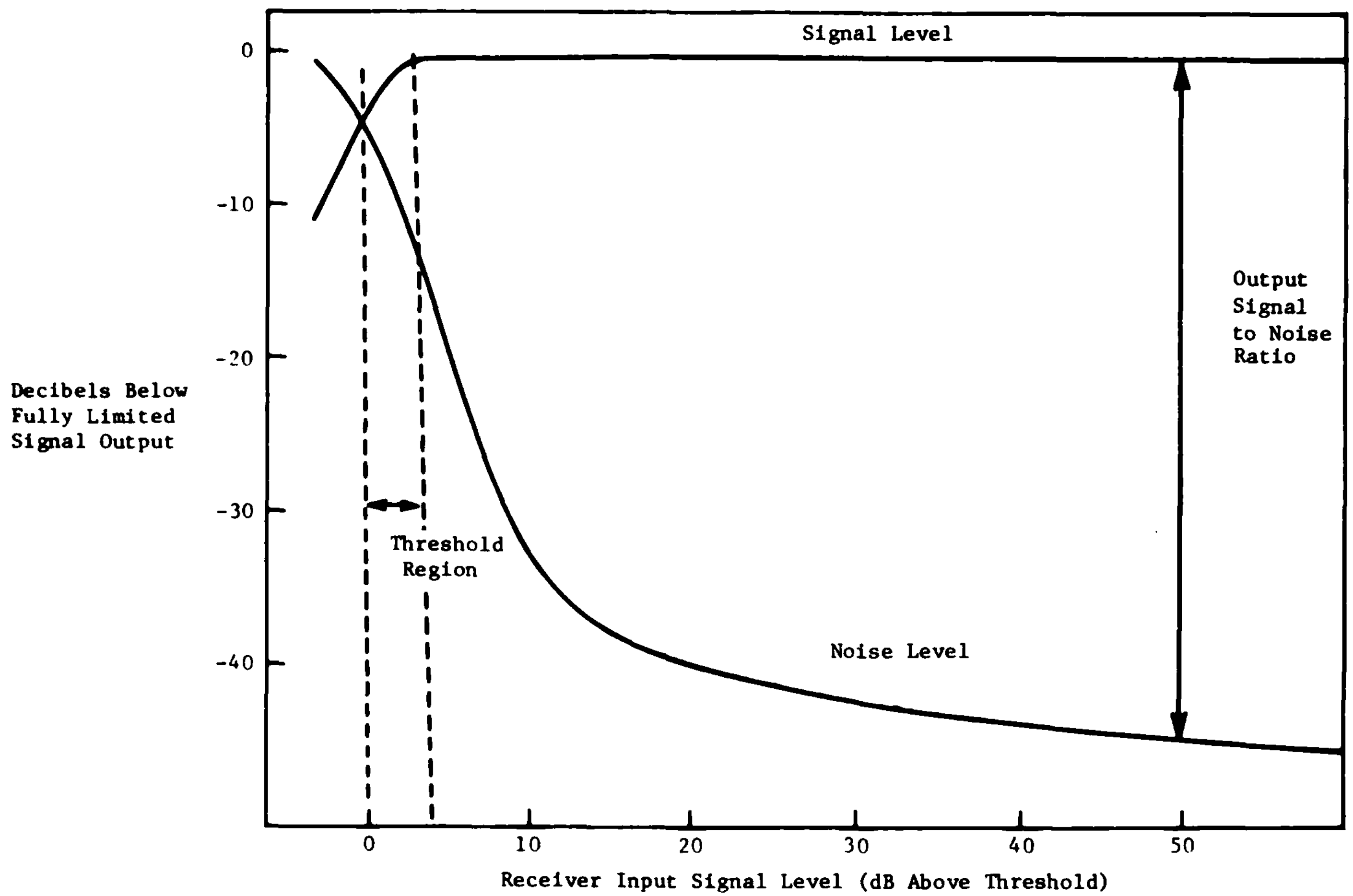


FIGURE 3-1
TYPICAL WIDEBAND FM DETECTOR PERFORMANCE

not excessive. On the other hand, communications as close-in as seven kilometers were not possible during the R/S tests at some sites due to inadequate signal strength.

To the east and south of the FAAR site, the FAAR overlooked a broad shallow valley beyond which the terrain, on the average, rose. Such topography is relatively well suited to line-of-sight communications. The terrain immediately to the north and west of the FAAR site rose higher than the FAAR. Beyond these higher features the terrain fell to lower elevations in both cases. Such topography degrades line-of-sight communications. The terrain throughout the area of testing was hilly and about 50% wooded.

All C/V tests were conducted to the east and south of the FAAR, consistent with the good fields of view the radar would have from its location in these directions. Relatively few sites yielding error-prone reception were encountered during these tests. During R/S testing, sites to the north, east, south, and west were assigned to the four outsite teams (see Section 2.2.2) respectively. Ninety-five percent of the sites having error-prone reception found during R/S testing were located to the west or north of the FAAR over the more adverse terrain. Appendix III shows some typical terrain profiles from successful and unsuccessful tests.

Analysis of all terrain profiles showed that whenever data link reception was error-prone or nonexistent at the outsites, adverse terrain profiles lay between the FAAR and the outsites. In some cases substantial terrain blockage could exist, yet communications were still excellent. A further relatively small increase in range or blockage would then be adequate to completely preclude communications.

Comparison of these results with the theoretically predicted effects of path profiles and ranges on the system's performance is beyond the scope of this report. MITRE will publish the results of such a separate analysis of these factors at a later date to supplement the results reported here.

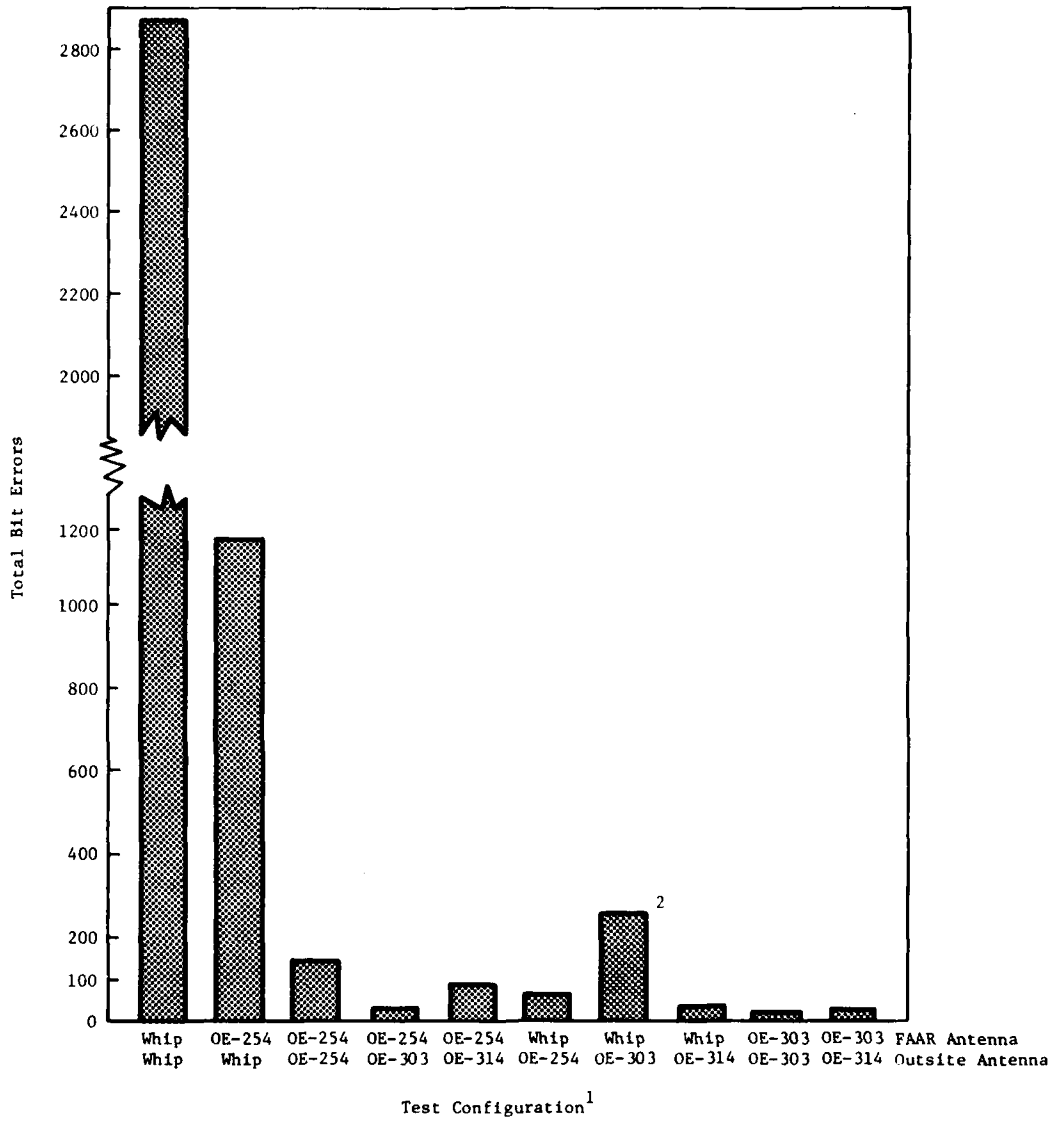
3.3 The Effect of Antennas on Performance

As noted in Section 2.2.1.3, four different antennas were evaluated to determine the relative improvements in link performance associated with each.

During the C/V tests, errors and weak received signals were concentrated predominately in tests using the AS-1729 whip at the outsite locations and either the whip or the OE-254 at the FAAR, as shown in Figure 3-2. The weakest signals observed were also noted under the same conditions.

Moreover, in those tests employing the whip at the FAAR and the OE-254 at the outsites, data link error rates and signal levels were consistently better than for the reverse case. This indicates that the AS-1729 whip mounted on the FAAR shelter had more gain than the same antenna mounted on a jeep, under the conditions tested. The higher antenna mount and better ground plane offered by the FAAR shelter roof may have accounted for much of this difference.

During the R/S tests in the second week, fewer antenna variations were used due to time constraints. All sites were tested using the whip at the outsite and both the whip and the OE-254 at the FAAR. Table III summarizes the results of these tests. At the nine marginal sites there was roughly a 10-fold improvement in error rates, on average, when the FAAR antenna was switched from the whip to the OE-254.



Note: 1. Only a small percentage of the tests had errors. See Table II.

2. Due to a suspect test using a damaged antenna.

FIGURE 3-2
BIT ERRORS BY ANTENNA TEST CONFIGURATION FOR C/V TESTS

TABLE III

PERFORMANCE SUMMARY FOR R/S TESTS

SITES WITH:	NUMBER	PERCENT
Excellent Reception	17	44
Marginal Reception	9	23
Reception Not Possible	13	33
Total Sites	39	100

Four tests were run using the OE-303 antenna at R/S test outsites. Results of these tests were compared to results using the whip under the same conditions. Three of these tests used the LETS. A fourth was done by qualitative voice check. Table IV shows the results.

TABLE IV

COMPARATIVE PERFORMANCE OF WHIP
AND HALF-RHOMBIC ANTENNAS AT R/S SITES

	TEST TYPE	WHIP AT OUTSITE	HALF-RHOMBIC AT OUTSITE
Test 1	DATA	No data reception	Zero errors
Test 2	DATA	939 errors	823 errors
Test 3	DATA	No data reception	Zero errors
Test 4	VOICE	Weak and unreadable	Loud and clear

In each of these four cases the antenna at the FAAR was not changed while comparing antennas at the outsite. The small reduction in errors when the OE-303 anntenna was substituted for the whip in

one test shown (Test 2) cannot be explained by the information collected and on hand. However, changing the outsite receive antenna from the whip to the OE-303 during this test improved the received signal substantially (around a 5-fold, or 7 decibel, increase). Moreover, in all four cases the OE-303 tests were conducted at sites where all previous attempts at data reception had been unsuccessful using either the whip or the OE-254 antenna at the FAAR and the whip at the outsite. Time limitations prevented further testing of the OE-303 antenna at R/S sites.

While there was no ECM in the tests, the more directional, narrow-beam OE-303 and OE-314 antennas would be expected to provide some resistance to jamming due to their decreased sensitivity at off angles compared to the omnidirectional antennas.

3.4 The Effect of Data Rates on Error Performance

Three different data rates were tested for each site and antenna combination. Six hundred bits per second was used as the lowest data rate used. This rate approximates the data rate currently used for broadcast from the FAAR to the TADDS. Tests were also conducted at 1200 and 2400 bits per second. These latter rates are under consideration for an improved FAAR data link.

The two lower rates were tested both with and without encryption while the 2400 bits per second rate was tested only over encrypted links. The nonencrypted tests used FSK modulated data signals while encrypted tests used digital baseband signals. The AN/VCR-12 will not support a 2400 bps binary FSK mode of operation through the microphone jack due to its audio bandwidth limitation.

In the majority of cases in which reception was possible, signal strengths were adequate to receive with no errors at all data rates. Under marginal conditions no significant degradation was observed when going from 600 to 1200 bits per second, or in going from 1200 to 2400 bits per second. Figure 3-3 summarizes these observations.

Since FSK at 2400 bps could not be tested, only encrypted digital baseband performance was compared for 1200 and 2400 bps data rates. The encryption device converts all signals to 16,000 bps for radio transmission. Hence, no appreciable difference in error rates should be expected when LETS data rates are changed in this mode of operation.

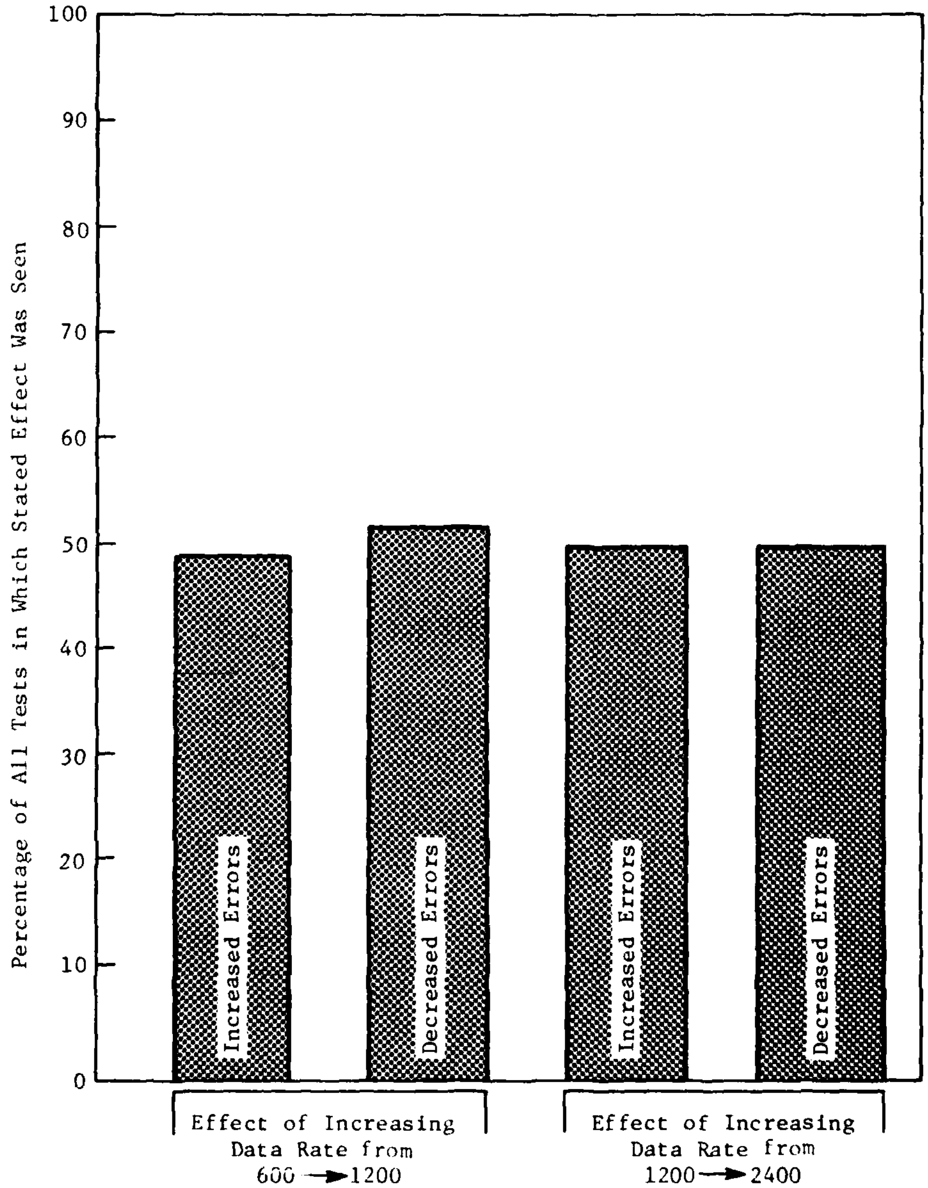
3.5 The Effect of Encryption and Interface on Performance

The U.S. Army has stated that it wants to encrypt future versions of the data link. But the Army requires the data link to operate without the cryptographic device as well. Since the cryptographic device performs best with digital signals, while the radio microphone jacks accept only audio FSK signals, both signals types were tested.

Figure 3-4 shows the relative effect on system performance that operation with encryption and low-level digital interfaces had, compared to unencrypted audio FSK interfaces. The small difference observed is statistically insignificant. The two approaches apparently gave equivalent performance.

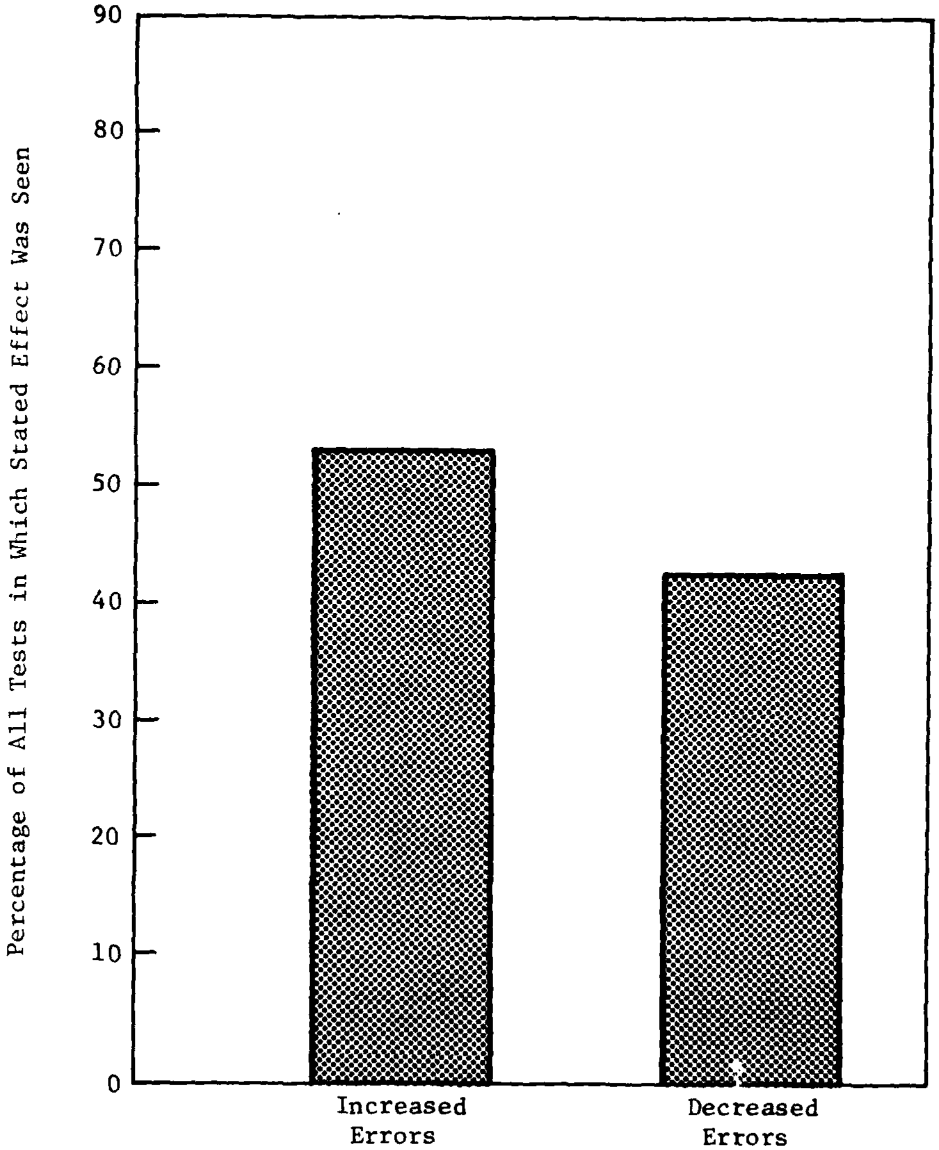
3.6 The Effect of FAAR Radar Radiation on Performance

In order to be sure the radar equipment was not contributing something that was influencing test results, the data link was tested with the radar on and off. Figure 3-5 compares the number of times



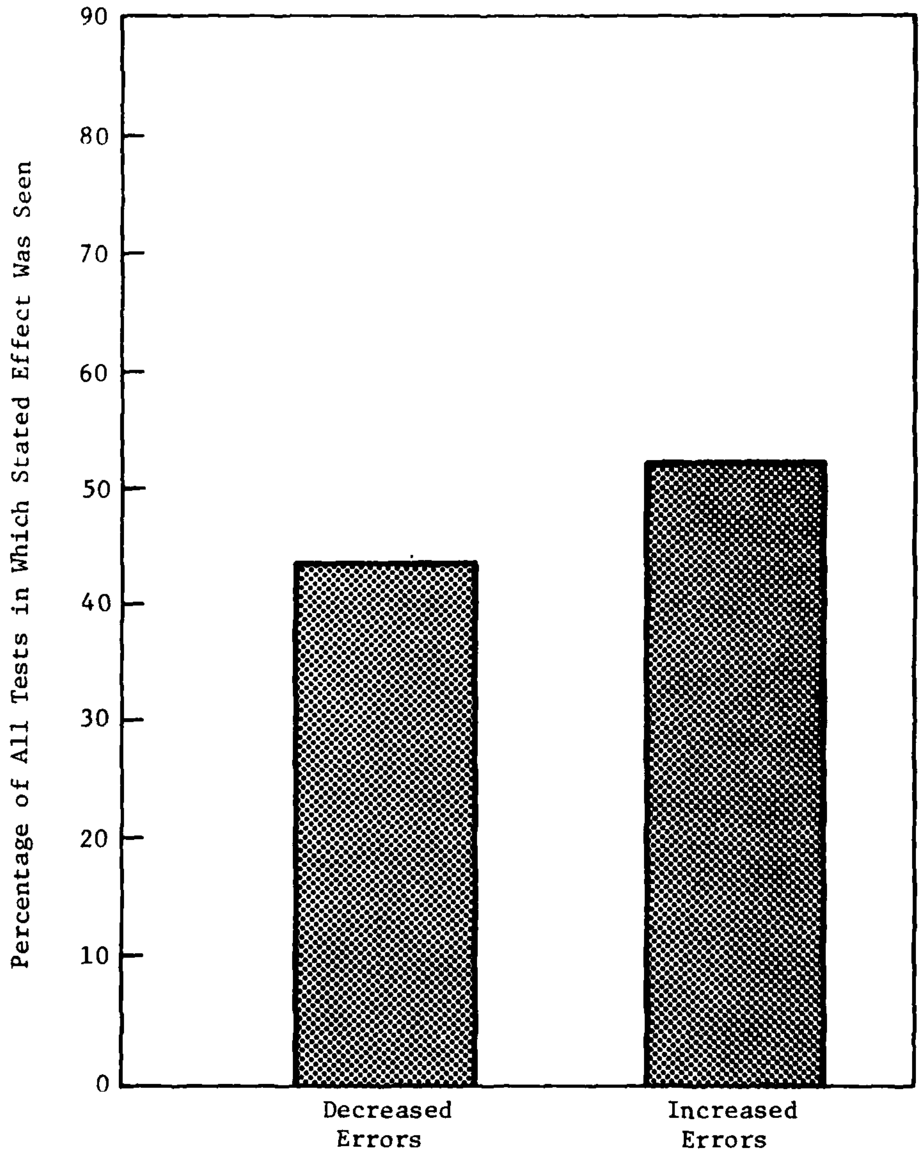
Note: For each comparison, only the data rate changed.

FIGURE 3-3
EFFECT ON TOTAL TEST SEQUENCE BIT ERRORS WHEN INCREASING THE DATA RATE



Note: For each comparison, only the interface approach (unencrypted FSK or encrypted baseband) changed.

FIGURE 3-4
EFFECT ON TOTAL TEST SEQUENCE BIT ERRORS WHEN CHANGING FROM UNENCRYPTED FSK TO ENCRYPTED BASEBAND



Note: For each comparison only the radar's radiation changed.

FIGURE 3-5
EFFECT ON TOTAL TEST SEQUENCE BIT ERRORS WHEN CHANGING FROM RADAR ON TO RADAR OFF

total errors were increased versus decreased when the radar transmitter was switched on. The radar antenna was rotating in all cases. As illustrated, there was no significant effect on the data link from FAAR radar energy radiation.

3.7 Error Distributions

The error totals and distributions from the LETS (see Section 2.2.1.4) help determine the intrinsic background error rate under good transmission and reception conditions and determine the intensity and duration of elevated error rates due to weak or noisier reception conditions. For each error rate identified the LETS error distributions can reveal the total amount of time that a particular error rate occurred during a test. But they cannot reveal how many separate times a specific error rate occurred. Nor can the error distributions reveal at what point in time during a test a given error condition occurred.

The background error rate* averaged over all the tests conducted can be inferred from the total number of tests having no errors (697) relative to the total number of successfully conducted tests (846) (see Table II). In the worst case it can be assumed that in each of the 149 tests having errors, one or more of those errors were due to the intrinsic background error rate. This corresponds to an intrinsic error rate of about 2×10^{-6}. This rate remained about the same for all modes and speeds tested.

*The background error rate is the small but finite error rate found when operating in optimum conditions which is due to design and component limitations in the equipment and natural characteristics of the channel.

Forty-nine tests had eight or more bit errors per test (10^5 bits). These tests were analyzed more closely to determine how errors tend to occur in more error-prone environments. In general, the following four additional characteristics were observed. In many cases a given test had two or more of these characteristics.

3.7.1 Intense Error Rates

Thirty-three (67%) of the 49 tests had errors grouped in brief but intense clusters. These clusters lasted altogether only a small fraction of a second, but they represented error rates higher than 10^{-1}. High amplitude noise impulses would account for these errors. These impulses could have been due to interference or FM detector click noise, for example.

3.7.2 Consecutive Errors

Thirty-three tests also had at least one instance of two or more consecutive errors. As expected, the occurrence of consecutive errors was very highly correlated with the observation of intense error rates described in 3.7.1 above. Again, strong noise or interference impulses would account for this behavior. But the total number of impulses per test was low in each case.

3.7.3 High Error Rate Bursts

Sixteen tests (33%) had errors that occurred in short bursts with error rates between 10^{-3} and 10^{-1}. As much as eight seconds of errors at these rates were observed per test. In some cases they were superimposed on a lower, more steady background error rate. Intense clusters of errors (described in 3.7.1) were also present in some tests having bursts.

3.7.4 Higher Than Normal Background Error Rates

Twelve tests (25%) had background error rates of greater than 10^{-4} lasting throughout the test. But in almost all cases this rate varied during the test over about one order of magnitude. Again, some of these tests had bursts (section 3.7.3) or impulses (section 3.7.1) as well.

3.7.5 Related Observations

The quantitative results of these error distribution analyses agree quite well with qualitative observations made in the field during the test. On-site observations using an oscilloscope showed that received signal levels tended to vary during the test. Under weak signal conditions this variation would explain the varying background error rates.

Moreover, noise and interference in the field were stronger and more erratic than that observed under controlled conditions. And occasionally test personnel reported interferring signals on the test frequency. These conditions could also account for the error distributions described above.

Therefore, both quantitative and qualitative observations show that error detecting and correcting schemes selected for an improved FAAR data link must therefore take both burst-like and more evenly distributed (i.e., "random") error distributions into account.

3.8 Qualitative Results

In addition to the quantitative data gathered over the course of the data link tests, MITRE suggests that the Army consider three additional factors when designing an improved data link.

3.8.1 Receiver Signal Level Meters

The signal level meters temporarily used with the R-442 receivers were very useful for measuring the strength of the data link signal. With this addition to the R-442 or other outsite data receiver, antennas and locations could be quickly checked for data reception quality. The operator could then easily select a good location for the antenna at the outsite. He could also optimize antenna height and orientation.* Because a small improvement in signal level at marginal sites can have a large positive effect on data link quality, this capability should be made available to SHORAD weapons teams using the FAAR data link.

3.8.2 Data Link Effect on Radar Display

During the data link tests, whenever the FAAR data link was transmitting, the FAAR PPI scope was filled with false returns or noise. This problem was severe enough that local low-level aircraft could not be tracked. While maintenance personnel troubleshooted the radar, no radar fault was isolated.

3.8.3 Other Antenna Differences

There were substantial differences in the amount of time required to set up and tear down each antenna. Table V shows the approximate times observed for the three antennas requiring erection (all but the whip).

*Sites were not fine-tuned for the data link tests.

TABLE V

ANTENNA SET-UP AND TEAR-DOWN TIMES

	MINUTES (APPROXIMATE)	
	SET UP	TEAR DOWN
OE-303	7	4
OE-254	15	10
OE-314	20	12

The SHORAD weapons team must pack up and redeploy on very short notice. Therefore, of the three higher gain antennas tested (the OE-303, OE-254, and OE-314), the OE-303 seemed best suited for use by those teams. The OE-303 is also smaller, lighter, and more rugged than the other two antennas and hence less of a burden.

The OE-314 multielement log periodic antenna was particularly sensitive to proper assembly and was fragile in comparison to the other antennas. Its elements would fall out if not properly installed. In addition the steering guys attached to the rear of the OE-314 yagi antenna tended to bend the antenna backwards. In some cases masts were damaged as a result. Putting additional guys on the front of the yagi would offset this tendency.

Appendix III contains other technical observations gathered during the tests dealing with data inversion, FSK operation, and transmitter keying.

4.0 CONCLUSIONS

In review, the following conclusions are drawn from the results of the European FAAR data link tests.

a. Alternative antennas can significantly improve overall data link performance.

1. Using higher gain antennas distinctly improved link performance in two ways at sites with weak reception. First, better antennas permitted communication to sites previously without any communications. Second, better antennas substantially reduced bit error rates observed at those sites that had high error rates when using whips.

2. The OE-303 directional half-rhombic antenna seemed well-suited for use at weapon outsites due to its superior performance, low bulk, ruggedness, quick set-up and tear-down capability, and reputed resistance to off-angle jamming. In addition, use of the OE-254 elevated omnidirectional antenna at the FAAR improved data link performance by improving received signal strengths.

b. The nature of the terrain between the FAAR and the simulated weapon outsites was more important than range in determining link reception quality and error rates for ranges up to 20 kilometers.

c. Encrypted data can be transmitted at rates at least as high as 2400 bits per second over the FAAR data link using an AN/VRC-12 series or similar radios. Under marginal field reception conditions there was no significant difference in system bit error rate performance when the data rate was raised to 2400 bps. If unencrypted binary FSK is to be transmitted through the radio audio circuits, radio design limitations do not permit any standard rates higher than 1200 bits per second to be used.

d. Data link tests at all data rates were in most cases either error-free or unreceivable. Only in one in seven instances (or 14%), on the average, did performance levels fall in between these extremes.

e. When operating with the weakest useable received signal levels at the data link receiver, a relatively small change in these levels produced a marked change in overall reception quality and error rates. The current data link receiver does not display received signal levels for optimizing reception.

f. Inclusion of encryption, and consequent changes from low-level digital to FSK formats, caused no significant change in link performance. Moreover, no change in link performance was noted with the presence or absence of radar radiation.

g. Both stationary and time-varying error rates were observed during the field tests. Under good reception conditions error rates were better than 10^{-5}. Under poor reception conditions error rates were higher and tended to vary in time during the test.

5.0 RECOMMENDATIONS

The above observations lead to the following recommendations:

a. Improve the FAAR data link on a near-immediate basis by:

1. Issuing OE-303 antennas to SHORAD weapons teams for use at weapons outsites,

2. Issuing the OE-254 antennas to FAAR teams for use at FAAR locations.

b. If the FAAR itself is to be improved, the Army, in addition:

1. Can use an encrypted 2400 bits per second link for FAAR to weapon outsite broadcasting, if required,

2. Should give the operator a means to read received signal levels for optimizing site selection and antenna installation,

3. Should compare the benefits and costs of incorporating an error detection and correction scheme versus improving received signal levels for reducing errors. Increased signal levels strongly improved bit error rates without the electronic complexity and extra message bits required for error detection and correction.

APPENDIX I

PLANNING PAPERS

This Appendix contains tables, diagrams, and forms which MITRE developed in the course of planning for the European SHORAD data link tests. They are included to illust· ·dvance planning steps taken by the test team. A brief description of each entry and how it was used follows.

The same people at MITRE and in the Army who were responsible for test planning also conducted the on-site tests. Therefore test plan development continued through the execution phase of the tests in Europe. As the schedule progressed, MITRE and CORADCOM agreed, often verbally, to a number of changes to the test plans. In this manner testing was optimized to the conditions of the moment. When, for example, it became evident during testing that additional would be available, MITRE and Army personnel jointly drafted and carried out supplemental test procedures. The documents in this appendix were original planning documents and do not reflect these changes.

I-1 List of Tasks

Lists of activities were prepared for the categories of Test Planning, Test Preparation, Test Conduct, and Test Evaluation. Lead and support responsibilities and target dates were established for each activity. These lists enabled MITRE to keep check on progress and to identify where (and when) additional effort was needed.

I-2 PERT (Program Evaluation Review Technique) Diagram

The PERT diagram showed the relationship of the main tasks and pointed out the critical path.

I-3 Field Activities Daily Plan

This plan described, in general, activities for each of the days on which testing was to have been accomplished. The plan helped ensure an orderly test schedule.

I-4 Hourly Schedule

Step-by-step test activities were scheduled to avoid slack time and questions such as "What do we do next?"

I-5 Training Schedule

MITRE prepared this outline and executed the activities listed to train the military and civilian personnel. These personnel then became the cadre around whom the test teams were built.

I-6 Outsite Procedures

These procedures guided the outsite (weapons) teams in conducting the field tests.

I-7 Instructions, Transmitter (FAAR) Site

These instructions describe operation of the MITRE-developed Link Evaluation Test Set (LETS) in the transmission mode.

I-8 Instructions, Receiver (Outsite or Weapons Site)

These instructions describe operation of the LETS in the receive mode.

I-9 Test Configuration Plan

A list of all configurations to be tested to facilitate planning and coordination.

I-10 Data Collection Form

Receiver operators at the test outsites used this form for recording test results obtained from the LETS.

I-1 LIST OF TASKS (Planning)

ACTION	RESPONSIBILITY CSEP/ CENSEI	MITRE	USAREUR
Write Test Plan		X	
Establish Test Objectives & Priority (error rate vs distance, HF performance)	X	X	
Determine Tests to be Conducted (equipment configuration, technical parameters, test input, frequency band, voice, digital data, security)		X	
Determine Data Which Must be Collected		X	
Design Data Collection Forms		X	
Write Tests Scripts (test order & description, back-up plans, realism)		X	
<u>IDENTIFY, SCHEDULE, & OBTAIN TEST SUPPORT</u>			
Identify, Schedule, & Obtain Resources (what, who, when, where, why)	X	X	(X)
People (operators, vehicle drivers, maintenance people, data takers, test observers)	X	X	X
Operational Equipment (test articles)	X	X	X
Support Equipment (vehicles, instrumentation (both measuring & maintenance)	X	(X)	X
Spares (operational equipment, normal spares)	X		X
Obtain Frequency Authorization			
Determine Frequency Band(s) Needed (including alternate)	(X)	X	
Decide When Frequency Authorization is Needed	X	X	
Obtain Frequency Authorization			X
<u>SELECT TEST SITES</u>			
Propose Candidate Test Sites Available			X
Select Likely Candidates	X	X	
Examine Likely Candidates (physically, and using sample measurements)	X	X	X
Choose Actual & Back-up Sites	X	X	

X LEAD ROLE
(X) SUPPORT ROLE

I-1 LIST OF TASKS
(Continued) (Preparation)

ACTION	CSEP/ CENSEI	MITRE	USAREUR
ASSEMBLE AND CHECK OUT EQUIPMENT			
Assemble & Check Out Operational Equipment (test articles - radios, crypto, antennas, etc.)	X		X
Assemble & Check Out Support Equipment (measuring, maintenance, test input, test recording)	X	X	X
TRAIN TEST PARTICIPANTS			
Prepare Training Plans	X		X
Train Test Personnel	(X)	(X)	X
Take Reference Measurements (in U.S. and, if actual eqpt. isn't shipped, overseas)	X	X	

X MAJOR ROLE
(X) SUPPORT ROLE

I-1 LIST OF TASKS

(Concluded) (Test Conduct)

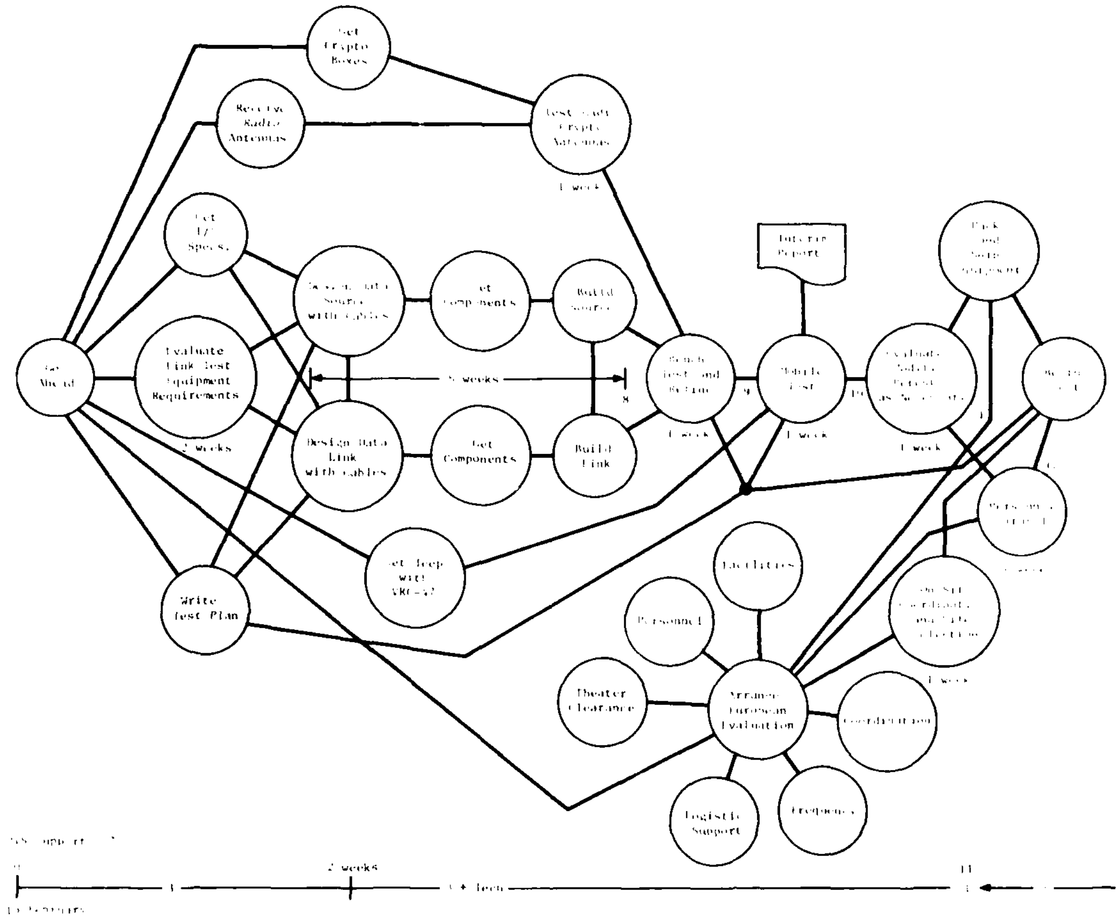
ACTION	CSEP/ CENSEI	MITRE	USAREUR
Ensure that all test articles and support equipment are available, calibrated & in place	X	X	X
Ensure that all personnel are available, understand their parts, and are in place	X	X	
Distribute Data Recording Forms			X
Review Data Recording Forms	X	X	
Coordinate and synchronize test conduct	X	X	X
Ensure that proper data are taken and collected		X	
Determine necessity for retest	X	X	

LIST OF TASKS

(TEST EVALUATION)

Determine required data reduction and data processing		X	
Reduce & process data	X	X	
Evaluate data	X	X	
Determine additional testing needed	X	X	
Prepare final report	(X)	X	

X MAJOR ROLE
(X) SUPPORT ROLE



I-2 : PERT DIAGRAM

FAAR DATA LINK EVALUATION

I-3

FIELD ACTIVITIES DAILY PLAN

Monday <u>May 12</u>	All players assemble. Go over script, duties, and coordination. Outside personnel move out to 5 km sites.
Tuesday <u>May 13</u>	1) Set up evaluation equipment and antennas and perform preliminary operations. 2) Conduct evaluations 1-4 and 8 on first antenna. Conduct evaluations 1-4 and 8 on each of the other four antennas. 3) Tear down equipment and move to next site.
Wednesday <u>May 14</u> through Friday <u>May 16</u>	Repeat activities of Tuesday, May 13, at 10, 15, and 20 km, except add to the evaluations Options 5-7 as time is available. On Thursday, May 15, conduct an evening series of tests at 15 km before tearing down equipment.
Monday <u>May 19</u> and Tuesday <u>May 20</u>	Conduct remainder of mandatory evaluations already completed. If there are none, conduct optional evaluations.
Wednesday <u>May 21</u>	Conduct remainder of optional evaluations.
Thursday <u>May 22</u>	Complete any outstanding evaluations.
Friday <u>May 23</u>	Cadre discuss results. Redeploy to garrison.

EUROPEAN COMMUNICATIONS FAAR LINK PERFORMANCE
HOURLY SCHEDULE
FAAR LINK EVALUATIONS

Test Schedule - Normal Test Day

TIME	ACTIVITY
0700	Assemble personnel
	Brief and discuss day's activities
	Discuss problems and lessons learned from previous day
	Assign sites, give instructions
	Verify operation of data sets
0800	Depart for outsites
	Power up FAAR equipment
0830	Arrive outsites
	Voice radio check using whip antenna on jeep
	Set up generator
	Set up RC-292
	If voice check okay, begin whip antenna evaluations (if not okay, go to RC-292 evaluations)
	Do data evaluations
	At end of each data sequence record output data and coordinate by voice with FAAR
1000	Switch to RC-292
	Do data evaluations
	Record data and voice coordinate after each evaluation
	Lower RC-292 and replace with OE-254
1130	LUNCH

EUROPEAN COMMUNICATIONS FAAR LINK PERFORMANCE
HOURLY SCHEDULE
FAAR LINK EVALUATIONS
(Concluded)

TIME	ACTIVITY
1230	Voice check OE-254
	Do data evaluations; record data and voice coordinate after each evaluation
1400	Lower and erect half-rhombic on same mast
	Voice check half-rhombic
	Do data evaluations
	Record data for each Voice coordinate for each
1530	Lower half-rhombic and erect log periodic antenna
	Voice check log periodic
	Do data evaluations
	Record results for each Voice coordinate after each
	Voice coordinate all day's evaluations thus far. Repeat as necessary
1700	As time permits:
	Do optional/night evaluations
	Record data for each Voice coordinate for each
	Reconfigure for and perform other evaluations as applicable
As Scheduled Each Day	Close evaluations and tear down
	Redeploy to assembly area
	Discussion and debrief; review next day's activities

TRAINING SCHEDULE

Wednesday - 7 May 1980

Morning

9 - 10 Background

Purpose: familiarize participant with the purpose and context of the European link evaluations.

Time required: 1 hour

Items discussed:

Army needs
Approach taken to fill those needs
Application of evaluation results
Limitations
Support required of unit

10 - 12 Demonstration of test sets

Time required: 2 hours

Items discussed:

Capabilities and limitations
Operating procedures
Interfaces with other equipment
Outputs and interpretations of outputs
Handling cautions and safety

Afternoon

Practical classroom test set exercises

Time required: 3 hours

Items covered:

Test set operation (back to back)
Data recording
Interface techniques
Output recording

I-5

TRAINING SCHEDULE

Thursday - 8 May 1980

Morning and Afternoon

Simulated Field Propagation Evaluation

FAAR located in motorpool

Jeeps in locations in and around Budingen

Purpose: To familiarize personnel with test equipment and procedures

Objectives:

1. Familiarization with employment of LETS in FAAR
2. Familiarization with employment of LETS in Jeep
3. Familiarization with employment of various antennas
4. Familiarization and refinement of operating and coordinating procedures

   Pretest coordination

   Past test coordination

   Data collection

5. Identification and resolution of other problems

Approach: FAAR and Jeeps will simulate a test deployment and complete all phases of evaluation procedures to be used at operational sites.

I-6

OUTSITE PROCEDURES

1. Attempt to establish voice communications by whip antenna on communications link. NOTE: The FAAR is net control station (NCS).

2. Emplace, connect, and power-up the generator.

3. Connect the test set to the radio.

4. Erect OE-303 antenna and establish voice communications on communications link with this antenna. If unable to communicate with the FAAR, attempt to relay through another outsite.

5. Verify (over communications link) reception of test message sent over data link.

6. Prepare for data link tests as instructed by the test director using the following table.

NOTE: The test director or his representative will determine actions to be taken in case any of the above steps cannot be successfully accomplished. If no communication is possible with any other site, personnel will be dispatched to this site as necessary to resolve the situation.

I-7

LETS INSTRUCTIONS TRANSMITTER SITE

1. Turn on power switch (on/off).
2. Turn mode switch to <u>baseband</u> or <u>FSK</u> as directed.
3. Turn crypto switch to <u>NORMAL</u> or <u>CRYPTO</u> as directed.
4. Press $\boxed{\text{RS}}$ reset.
5. Press $\boxed{\text{AD}}$ key.
6. Enter 2000.
7. Press $\boxed{\text{GO}}$.
8. Press $\boxed{\text{E}}$.
9. Press $\boxed{\text{B}}$ (for Binary) (or $\boxed{\text{F}}$, for FSK, as directed).
10. Enter 06 (or 12, or 24) as told by test director.
11. Press $\boxed{\text{GO}}$ (Display will go out).
12. If 06, 12, or 24 entered, wait five minutes.
13. After five minutes, press $\boxed{\text{ST}}$ (STOP).
14. Wait one minute. Read Display.
15. Go back to step 3, except enter 12 in step 10.
16. Repeat, except enter 24 in step 10.

LETS INSTRUCTIONS RECEIVER SITE

1. Turn power switch (on/off).
2. Turn mode switch to <u>baseband</u> or <u>FSK</u> as directed.
3. Turn crypto switch to <u>NORMAL</u> or <u>CRYPTO</u> as directed.
4. Check that all displays are on.
5. Press $\boxed{\text{RS}}$ (reset).
6. Press $\boxed{\text{AD}}$ (address).
7. Enter 2200.
8. Press $\boxed{\text{GO}}$.
9. Press $\boxed{\text{C}}$.
10. Press $\boxed{\text{B}}$ (or [illegible] , as directed).
11. Enter 06 (or 12, or 24) as directed.
12. Press $\boxed{\text{GO}}$ (Display will go out).
13. When display returns (*comes back on*), *it will indicate* CB06 (or CF06, (or 12, or 24).
14. Push [illegible] $\boxed{\text{AD}}$ then $\boxed{\text{0}}$ $\boxed{\text{0}}$ $\boxed{\text{5}}$ $\boxed{\text{0}}$ display will read CC in last two positions.
15. Push $\boxed{+}$: display will read 0051 05.
16. Push $\boxed{+}$ $\boxed{+}$ $\boxed{+}$ display will read 0054 CE.
17. Push $\boxed{+}$; display will read 0055 DD.*
18. Enter the last two (fifth & sixth) digits (in the right of the display) into boxes 1 and 2 on data collection form.
19. Push $\boxed{+}$, display will read 0056 DD.*
20. Enter the last two digits into boxes 3 and 4.
21. Push $\boxed{+}$; display will read 0057 DD.*
22. Enter the last two digits into boxes 5 and 6.

---

*D = digit

LETS INSTRUCTIONS RECEIVER SITE (Concluded)

23. Push $\boxed{+}$; display will read 0058 dE.

24. Push $\boxed{+}$; display will read 0059 DD.*

25. Push $\boxed{+}$; display will read 005A DD.*

26. Push $\boxed{+}$; display will read 005B DD.*

27. Etc. until you get EE when you press $\boxed{+}$.

28. For next test, go back to step 2, but enter new baud rate in step 11, as directed.

---

*D = digit

TEST CONFIGURATION PLAN

DATA LINK TESTS				VOICE COORDINATION COMMUNICATIONS LINK	
TEST	FAAR	OUTSITE	FORMAT	FAAR	OUTSITE
1a	WHIP	WHIP	1200F	OE 254	OE 303
b			600F		
c			2400B		
d			1200B		
e			600B		
2a	OE 254	WHIP	1200F	WHIP	OE 303
b			600F		
c			2400B		
d			1200B		
e			600B		
3a	OE 254	OE 254	1200F	WHIP	OE 303 or OE 314
b			600F		
c			2400B		
d			1200B		
e			600B		
4a	OE 254	OE 303	1200F	WHIP	OE 254 or OE 314
b			600F		
c			2400B		
d			1200B		
e			600B		
5a	OE 254	OE 314	1200F	WHIP	OE 303
b			600F		
c			2400B		
d			1200B		
e			600B		
6a	WHIP	OE 254	1200F	OE 254	OE 303
b			600F		
c			2400B		
d			1200B		
e			600B		
7a	WHIP	OE 303	1200F	OE 254	OE 254
b			600F		
c			2400B		
d			1200B		
e			600B		
8a	WHIP	OE 314	1200F	OE 254	OE 303
b			600F		
c			2400B		
d			1200B		
e			600B		

NOTE: ALL BASEBAND (B) LINKS CHECKED FIRST WITH VOICE TRANSMISSION THROUGH THE CRYPTO

F = FSK B = BASEBAND

I-10
DATA COLLECTION FORM

INSTRUCTIONS & DATA COLLECTION FORM 1 (RECEIVE SITE)

SITE ______ OPERATOR ______ DTG ______ RANGE ______ km

WEATHER & NOTES ______

TURN ON POWER TURN SWITCH TO MODE BASEBAND FSK DATA RATE ______

TURN SWITCH TO NORMAL OR CRYPTO ______

KEY IN:

RS AD 2 2 _ _ GO _ 5 _ _ GO (DISPLAY GOES OUT)

(WHEN DISPLAY RETURNS, DISPLAY WILL READ _ _ C b _ _) NO. U's ______

KEY IN:

RS AD _ _ 5 _

DATA DESCRIPTION	DATA LABEL	DATA +	+	+	+
Cycles Completed	C C				
Total Character Errors	C E				
Total Bit Errors	d E				
Bit "0" Errors	d 0				
Bit "1" Errors	d 1				
No. Errors 1 bit apart	E 0				
2-3 bits apart	E 1				
4-7 bits apart	E 2				
8-15 bits apart	E 3				
16-31 bits apart	E 4				
32-63 bits apart	E 5				
64-127 bits apart	E 6				
128-255 bits apart	E 7				
256-511 bits apart	E 8				
512-1023 bits apart	E 9				
1024-2047 bits apart	E A				
≥ 2048 bits apart	E b				

IF DATA RATE IS	ENTER	
600	0	6
1200	1	2
2400	2	4

I-10
DATA COLLECTION FORM

DATA DESCRIPTION	DATA LABEL			
1 consecutive bit error	C 1 0094	0095	0096	[illegible]
2 consecutive bit errors	C 2 0098	0099	009A	[illegible]
3 consecutive bit errors	C 3 009C	009D	009E	[illegible]
4 consecutive bit errors	C 4 00A0	00A1	00A2	[illegible]
5 consecutive bit errors	C 5 00A4	00A5	00A6	[illegible]
6-7 consecutive bit errors	C 6 00A8	00A9	00AA	[illegible]
8-9 consecutive bit errors	C 7 00AC	00AD	00AE	[illegible]
10-14 consecutive bit errors	C 8 [illegible]	[illegible]	[illegible]	[illegible]
15-19 consecutive bit errors	C 9 [illegible]	0065	[illegible]	[illegible]
20-29 consecutive bit errors	d 2 [illegible]	[illegible]	[illegible]	[illegible]
30-49 consecutive bit errors	d 3 [illegible]	[illegible]	[illegible]	[illegible]
50-99 consecutive bit errors	d 4 [illegible]	[illegible]	[illegible]	[illegible]
100 or more consecutive bit errors	d 5 [illegible]	[illegible]	[illegible]	[illegible]
END OF ERRORS	E E [illegible]	[illegible]	[illegible]	[illegible]

*IF DATA RATE IS	ENTER	
600	0	6
1200	1	2
2400	2	4

APPENDIX II

A SAMPLE OF TERRAIN PROFILES

This appendix contains illustrations of terrain profiles encountered during the FAAR data link tests. They show conditions under which excellent, marginal, and no communications were possible during the "Redeye/Stinger" testing, in which many sites were sampled. The profiles shown here were selected from sites assigned to teams C and D. Team C tested sites to the south of the FAAR where the terrain favored line-of-sight communications (reference Section 3.2 of the basic document). Only one site of 11 that team C tested would not support communications. Team D, on the other hand, tested sites to the west of the FAAR, when the terrain was less favorable for reception. Only one of team D's sites provided good communications. All sites were tested using only the AS-1729 whip antenna except as noted. Only sites showing some adverse terrain characteristics are shown.

No correction was made in the attached profiles for curvature of the earth and standard atmospheric refraction. Over the short ranges illustrated, these corrections are very small. At ten kilometers these factors together account for an effective increase of only two meters in terrain blockage at the midpoint (point of maximum effect) over that shown in the accompanying profiles. At 15 kilometers range these factors amount to 4.4 meters of increased terrain blockage.

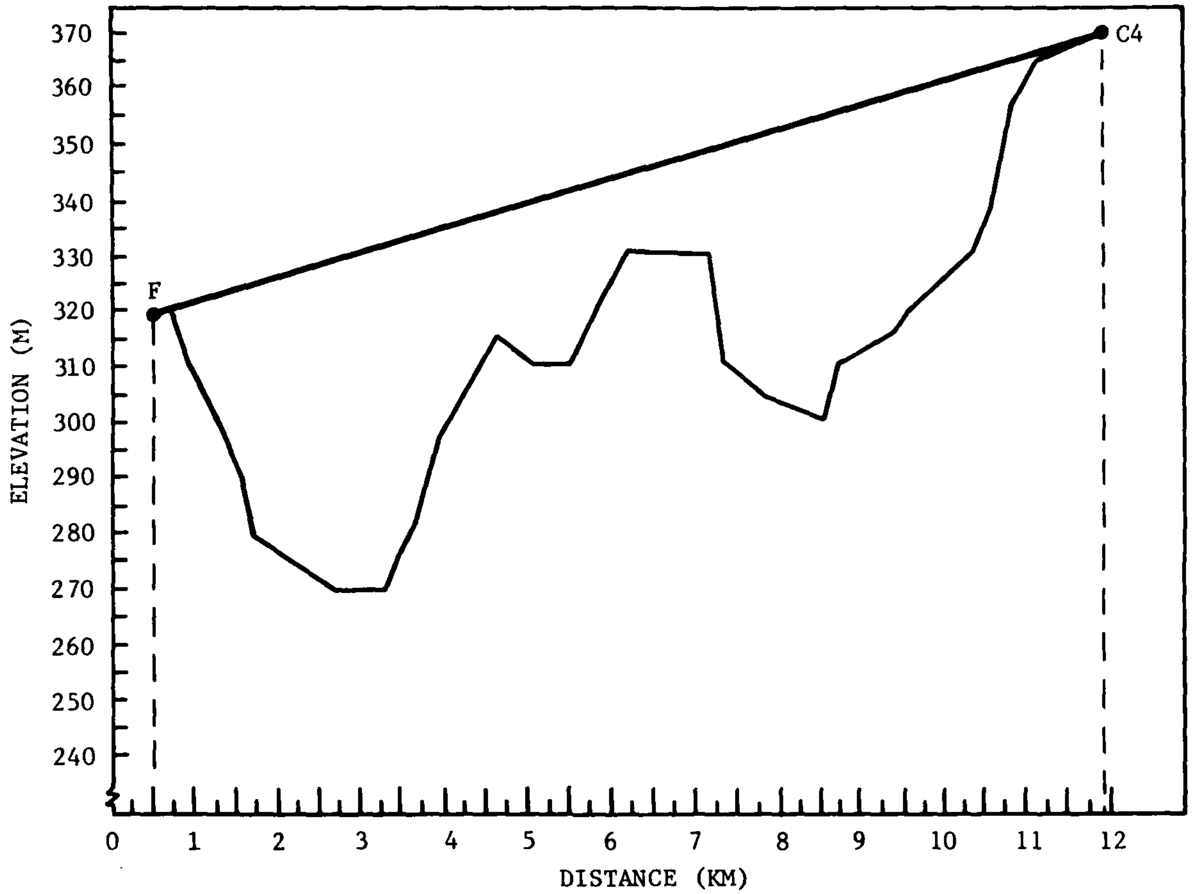


FIGURE II-1
TERRAIN PROFILE TO SITE C4
EXCELLENT RECEPTION

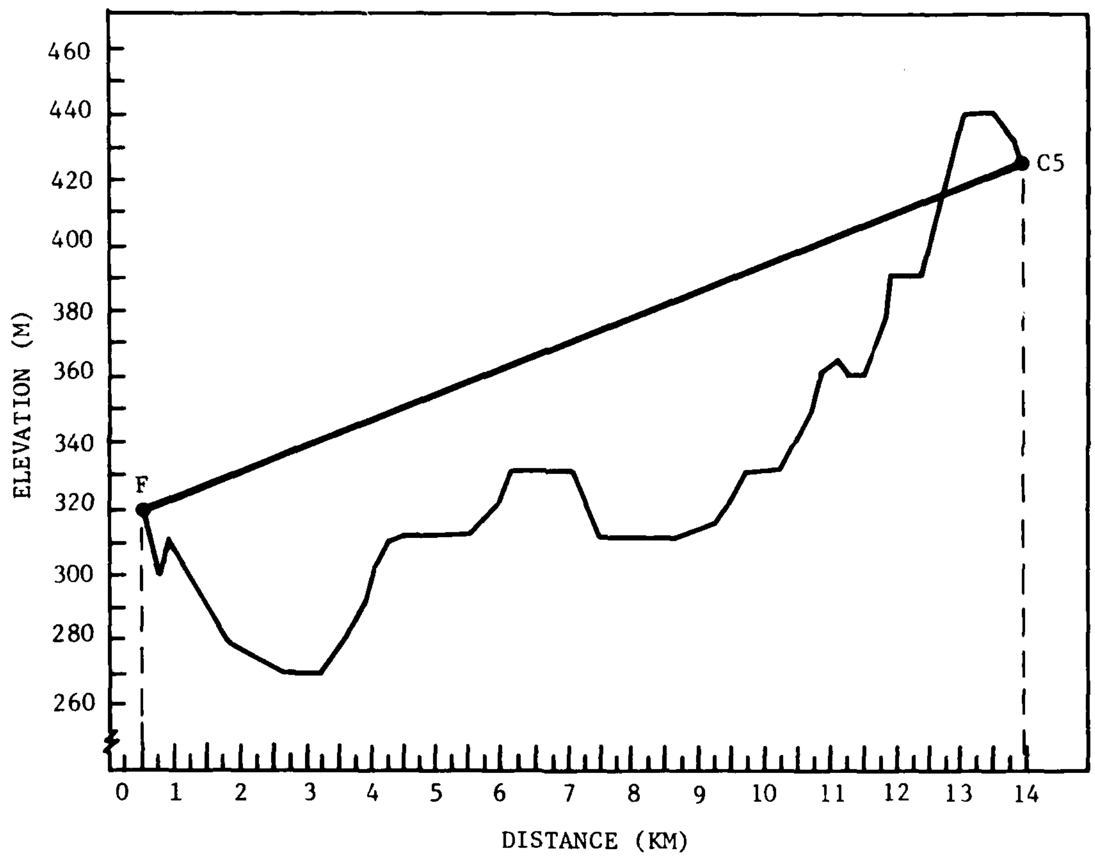


FIGURE II-2
TERRAIN PROFILE TO SITE C5
NO RECEPTION

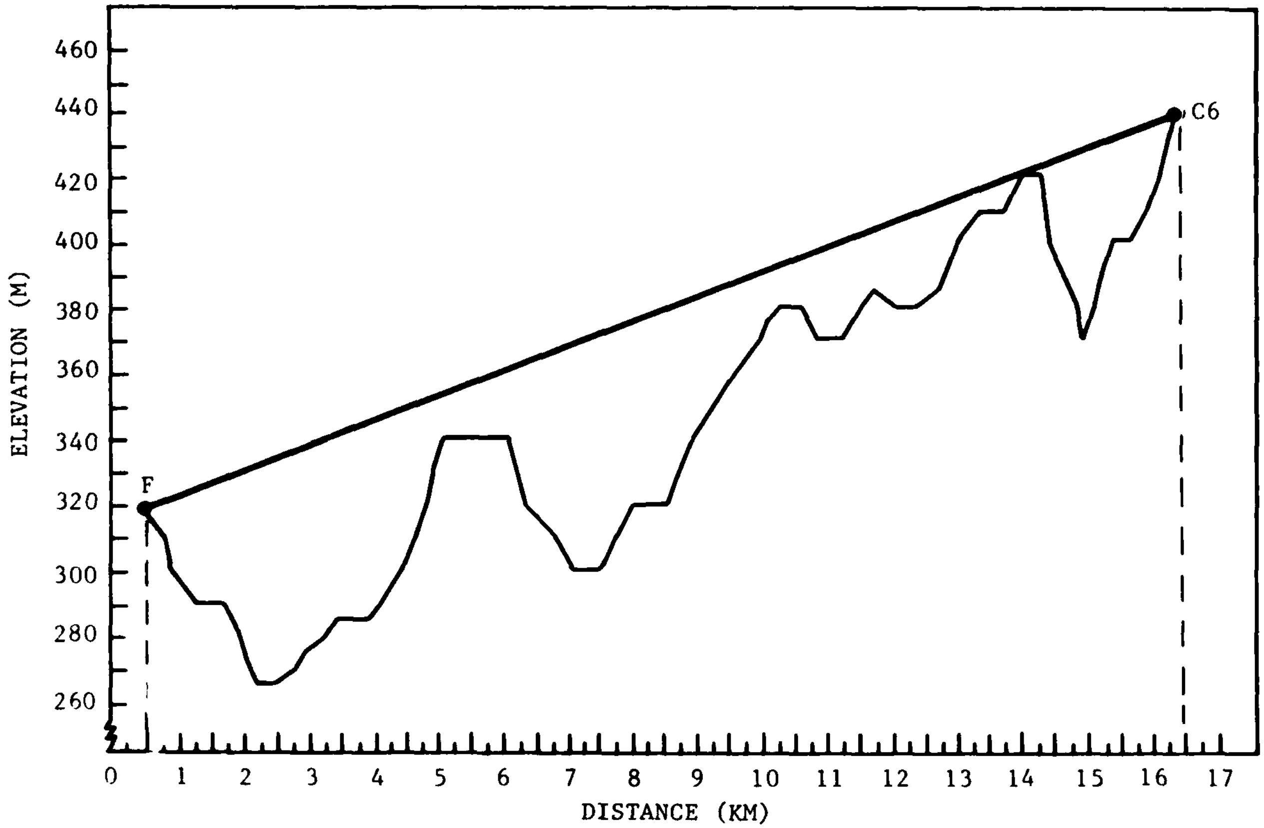


FIGURE II-3
TERRAIN PROFILE TO SITE C6
EXCELLENT RECEPTION

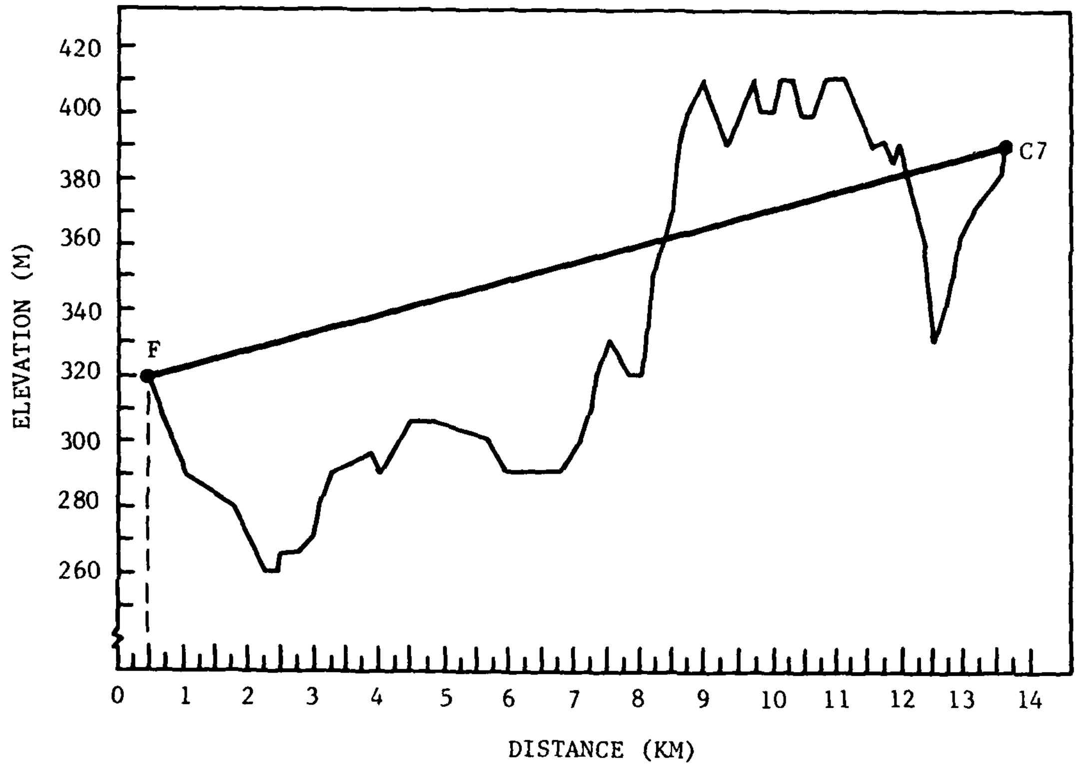


FIGURE II-4
TERRAIN PROFILE TO SITE C7
MARGINAL RECEPTION

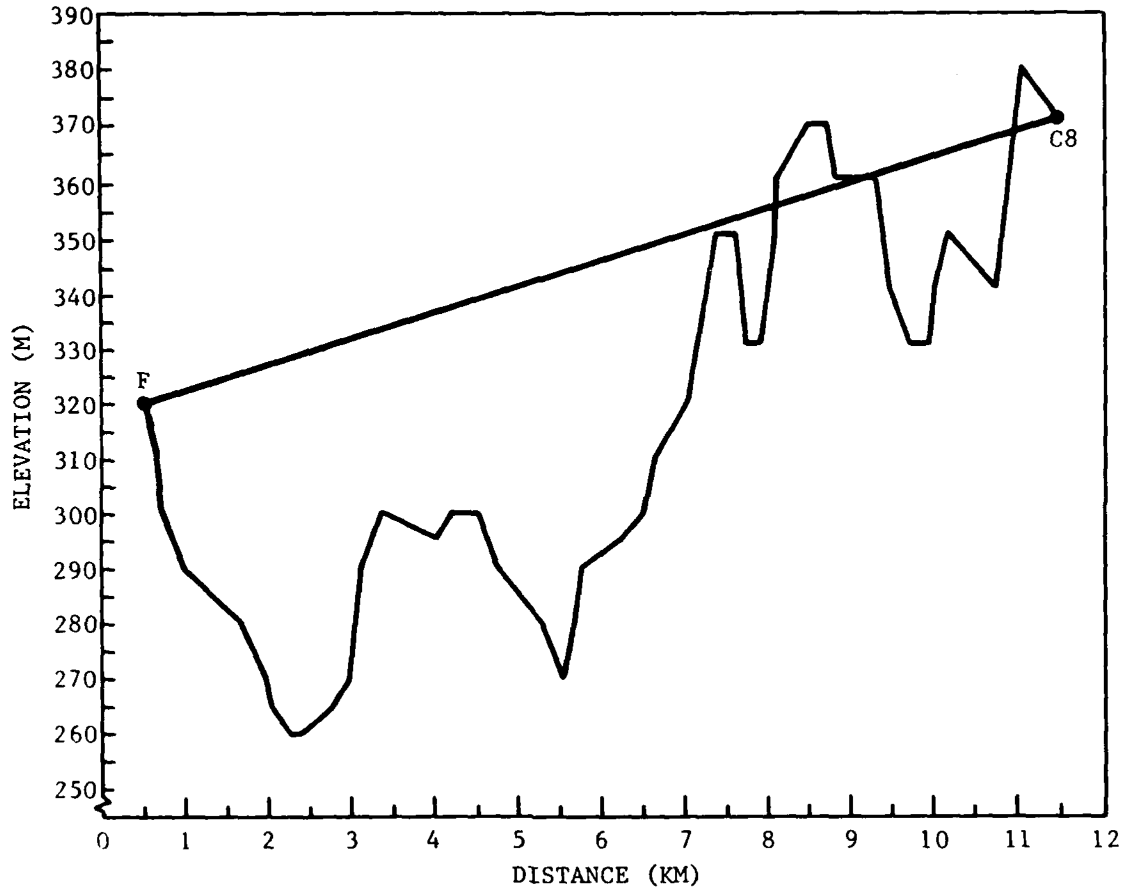


FIGURE II-5
TERRAIN PROFILE TO SITE C8
EXCELLENT RECEPTION

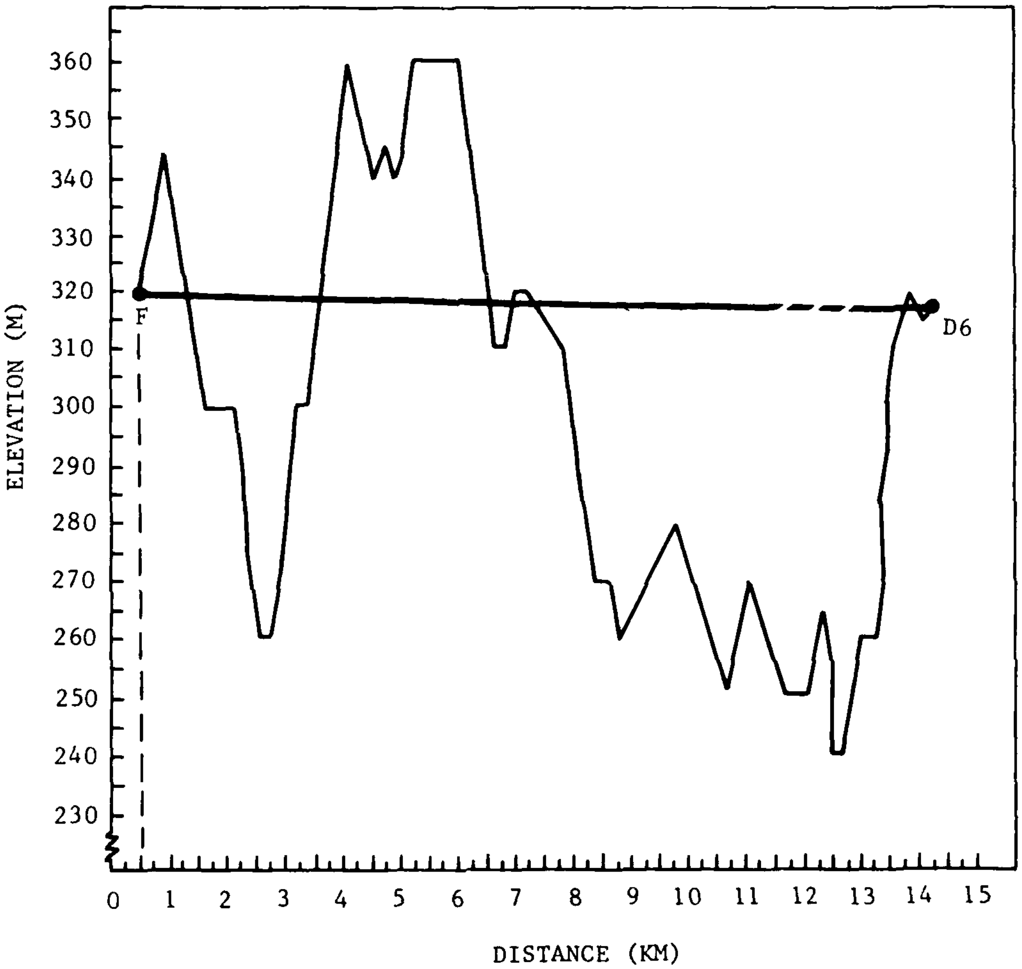


FIGURE II-6
TERRAIN PROFILE TO SITE D6
NO RECEPTION ON WHIP

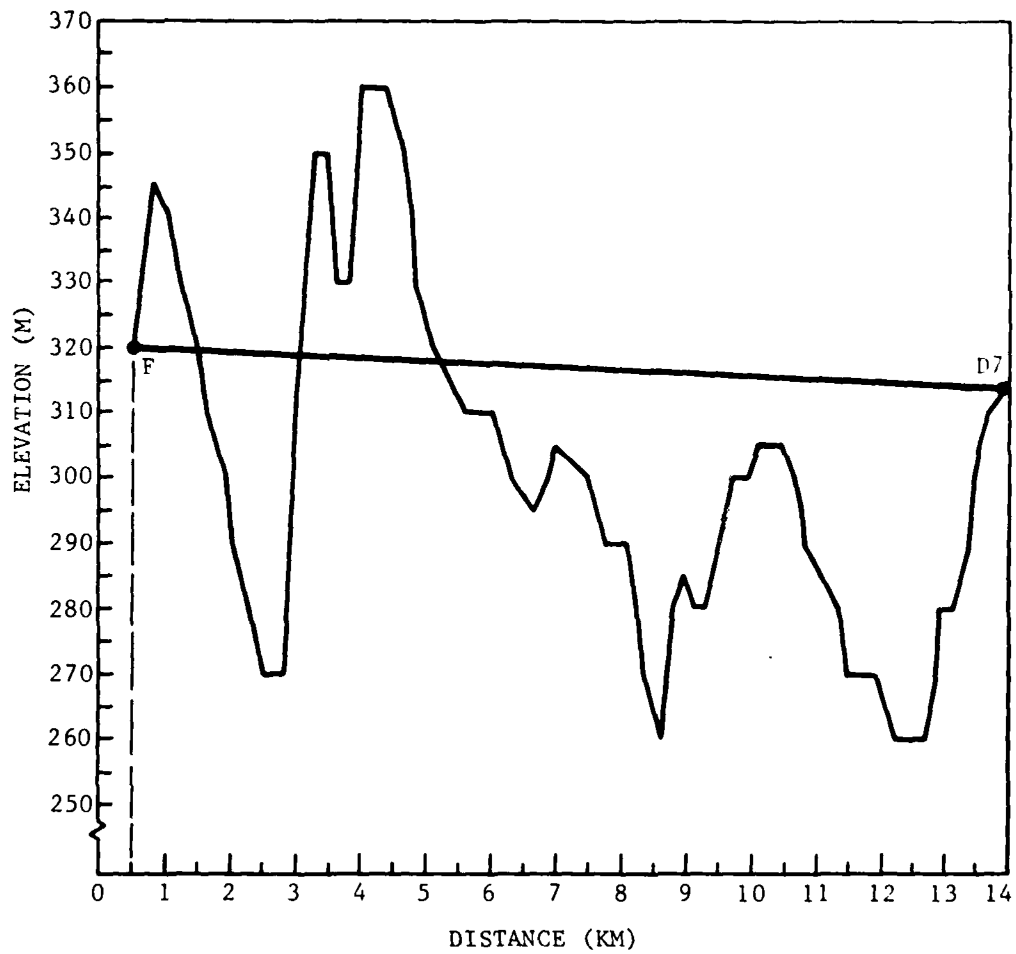


FIGURE II-7
TERRAIN PROFILE TO SITE D7
MARGINAL RECEPTION ON WHIP
EXCELLENT RECEPTION ON OE-303

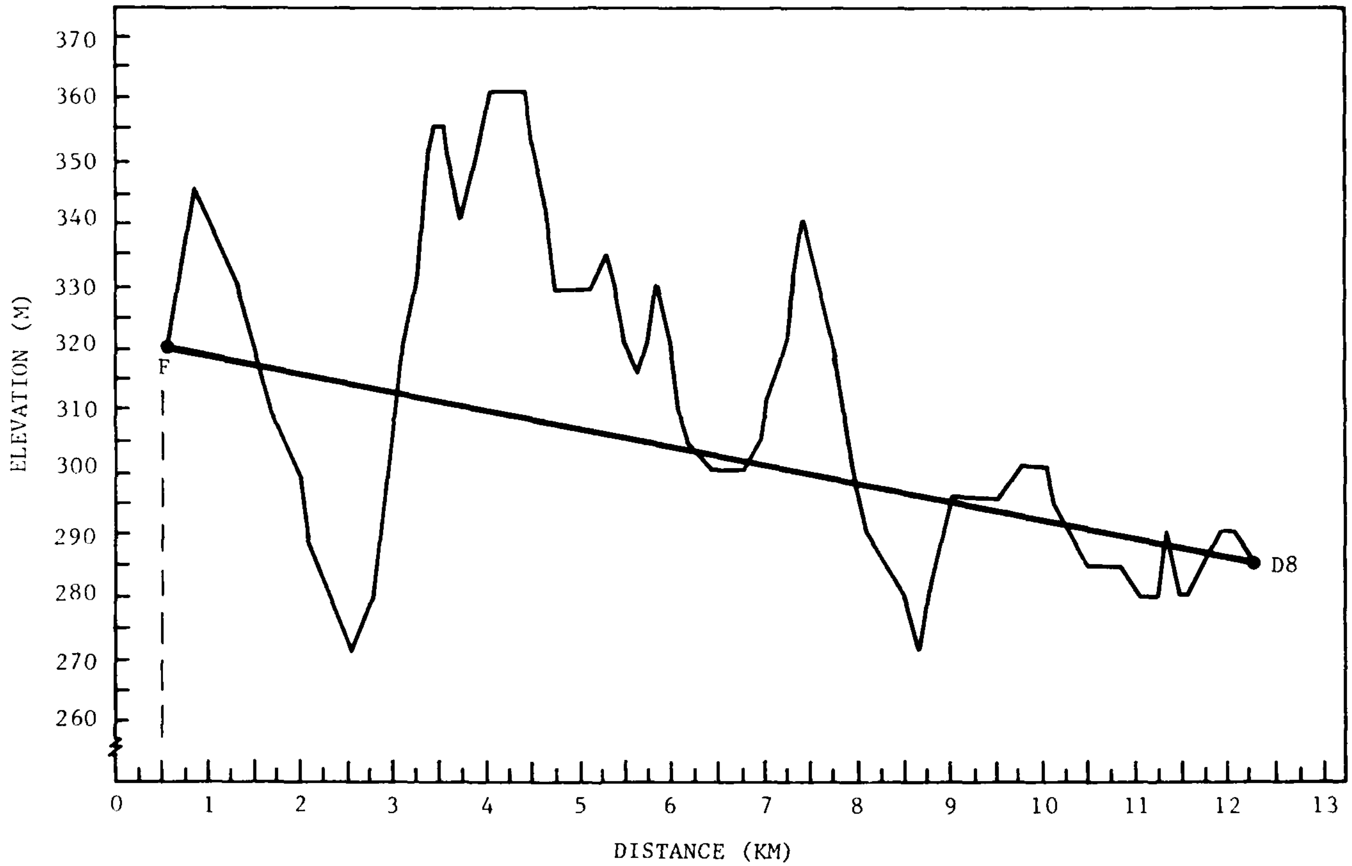


FIGURE II-8
TERRAIN PROFILE TO SITE D8
NO RECEPTION ON WHIP
EXCELLENT RECEPTION ON OE-303

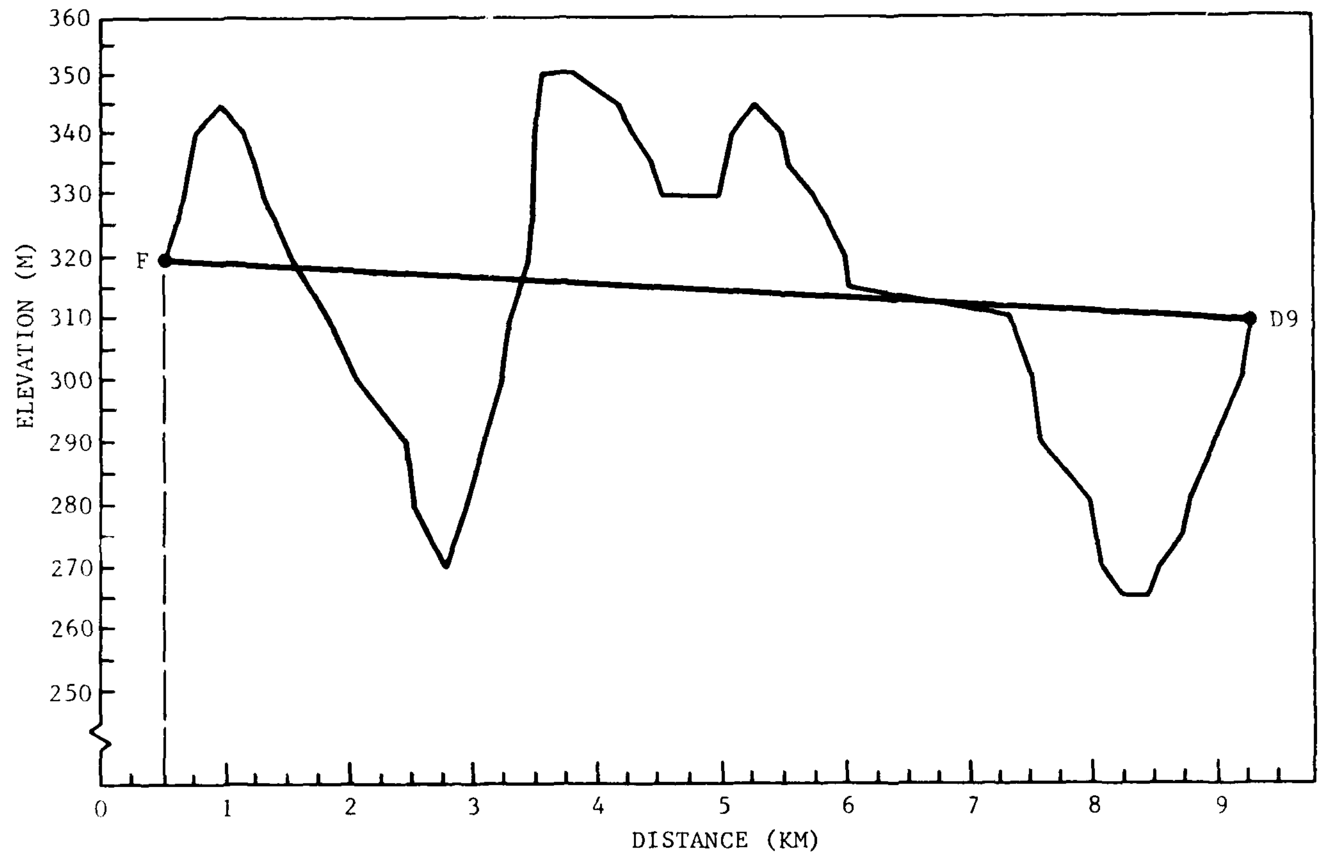


FIGURE II-9
TERRAIN PROFILE TO SITE D9
NO RECEPTION ON WHIP

APPENDIX III

ADDITIONAL OBSERVATIONS NOTED DURING EUROPEAN FAAR DATA LINK TESTING

1. General

The following observations were made during the course of the FAAR data link evaluation. While they do not bear directly on providing answers to the stated objective of the evaluation, they did affect the performance of the data links during testing. They are provided here for consideration in the eventual data link design.

2. AN/VRC-12 Data Inversion

During initial testing of the LETS in conjunction with the AN/VRC-12 series radios, it became apparent that when transmitting low-level digital information through the X-mode port of the radios (using the encryption device) the received data stream at the distant end was inverted relative to the transmitted data stream. The Army will be fielding new receiver modules that, among other things, will eliminate the inversion. However, there will be a period of time in which some radios will invert and some will not. Therefore, any data system using AN/VRC-12 series radios for transmission should be designed to be insensitive to the presence or absence of polarity inversion.

This problem does not affect communications employing audio-frequency FSK to interface with the radios. There is presently no data system in use in the field employing low-level digital interfacing with the AN/VRC-12 series radios, so that this problem has not been previously encountered in the field.

3. FSK Operation Through the AN/VRC-12

Normally the user connects to the AN/VRC-12 radio through a front panel microphone or speaker jack, controlled by the set's volume control. FSK modems are sensitive to volume levels and will not operate when the volume level is set too low (or fully off). In some cases overdriving the modem with an excessive volume setting will also cause erratic performance. Both problems were observed during the field tests. These problems can be avoided by interfacing with the radios at the rear multipin jack, where a constant level output is available. But this is awkward. Alternatively, an FSK interface modem can be designed that will operate with a wide dynamic range. In this case it would only be necessary to insure that the volume setting is not in the full quiet position.

During the tests it was discovered that the presence of the 150 Hz AN/VRC-12 "new squelch" tone superimposed on the output signal caused erratic FSK demodulator performance. The specific type of modem used in the LETS (a phase-locked loop type) may have been particularly sensitive to such tones. Since the radio does not adequately filter this tone from the output signal, any FSK data device used with these radios should supress this tone.*

4. AN/VRC-12 Keying

During testing of the LETS with the AN/VRC-12 radios, a very high reverse voltage transient appeared on the radio keying line when switching from transmit to receive. To avoid circuit damage it was necessary to provide a low impedance shunt for this transient in the LETS. Other terminal devices designed to operate with these radios should be similarly protected.

---

*It was found that the RT-524 transmitted this tone in all positions except the "old squelch on" position.

5. Other Observation

Receiver signal levels and consequent link error rates differed when measured at different times of the day for the same receiver and antenna configuration. Restrictions in time available prevented additional investigation or verification of this affect.

LIST OF ABBREVIATIONS

ADCCS	Air Defense Command and Control Systems
ADCII	American Standard for Communications Information Interchange
bps	bits per second
CSEP	Communication Systems Engineering Program
C/V	Chaparral/Vulcan
ECM	Electromagnetic Counter Measures
FAAR	Forward Area Alerting Radar
FM	Frequency Modulation
FSK	Frequency Shift Keying
Hz	Hertz (cycles per second)
LETS	Link Evaluation Test Set
PPI	Plan Position Indicator
R/S	Redeye/Stinger
SHORAD	Short Range Air Defense
TADDS	Target Alert Data Display System
VHF	Very High Frequency

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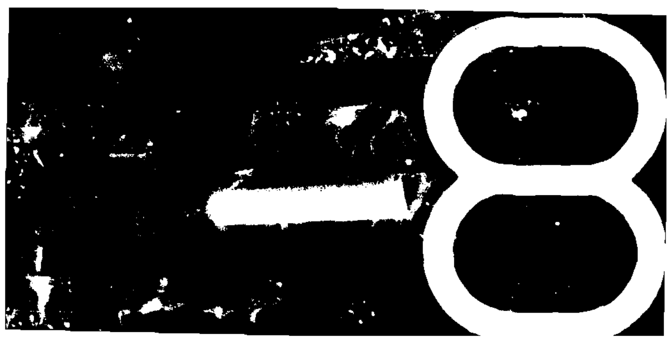
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